

Mines and Minerals Division

**Ontario Geological Survey
Aggregate Resources Inventory
Paper 113**

**Aggregate Resources Inventory of
Essa and Tosorontio Townships
Simcoe County
Southern Ontario**

**by Staff of the Engineering and Terrain Geology
Section, Ontario Geological Survey**

1988



**Ministry of
Northern Development
and Mines**

Sean Conway, Minister of Mines

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Aggregate Resources Inventory of Essa and Tosorontio Townships Simcoe County

**by
Staff of the Engineering and Terrain Geology Section**

1. Project supervisors: I. Szoke and Dale W. Scott; field work and report by R. Gorman; compilation and drafting by the staff of the Aggregate Assessment Office. The Mineral Resources Staff of Huronia District and Central Region of the Ministry of Natural Resources assisted in the collection of data, field checking and review of this report.

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Abstract

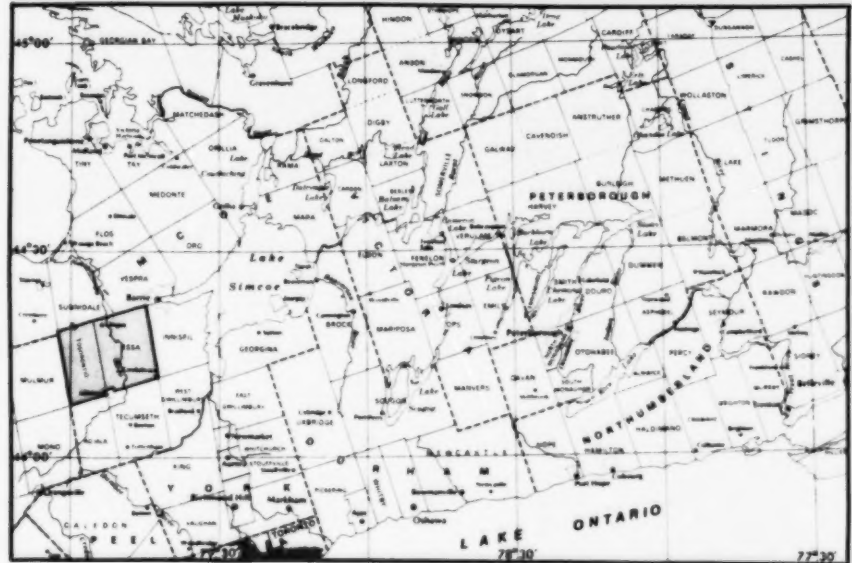


Figure 1. Key Map Showing the Location of Essa and Tosorontio Townships, Scale 1:1 800 000.

This report includes both an inventory and evaluation of sand and gravel as well as bedrock resources in Essa and Tosorontio Townships. The report is part of the Aggregate Resources Inventory Program for townships and municipalities designated under the Pits and Quarries Control Act.

In Essa and Tosorontio Townships, three areas have been selected for possible resource protection at the primary level. The primary selected areas occupy 2900 acres (1170 ha), exclusive of licenced properties. An estimated 1740 acres (700 ha) are currently available for extraction, containing resources of approximately 52 million tons (47 million tonnes). The parts of the selected areas which are available for extraction represent 3 percent of the total area occupied by sand and gravel deposits in the townships and 2 percent of the total original tonnage.

Selected Area 1 is located in the Boyne River outwash valley and contains coarse granular material suitable for many road-building and construction products. This outwash is the townships' most important aggregate source and it contains an estimated 28 million tons (25 million tonnes) of sand and gravel. Selected Areas 2a, 2b and 3 are glaciofluvial and glaciolacustrine deposits which contain an estimated 24 million tons (22 million tonnes) of sand and gravel.

In addition to these primary deposits, all of the remaining glaciolacustrine beach deposits and ice-contact stratified drift deposits have been selected at the secondary level of significance. Two bodies of glaciofluvial outwash have also been selected. Although the secondary deposits are not considered to be the best resources, they are an important part of the townships' total aggregate supply.

Essa and Tosorontio Townships are underlain by a succession of Middle and Upper Ordovician strata of the Verulam, Lindsay, Blue Mountain and Georgian Bay Formations. The great thickness of the overlying glacial sediments prevents any of the formations from being selected for possible resource protection.

Selected Resource Areas are not intended to be permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Introduction

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1984, the total tonnage of mineral aggregates extracted was 109 million tons (99 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Weatherson 1986).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be

based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand and gravel resources as well as a discussion on the potential of bedrock-derived aggregate. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

Part I — Inventory Methods

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References) as well as field examination of potential resource areas. Field methods include the examination of natural and man-made exposures of granular material. Most observations are made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites include estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations are also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, subsurface materials may be assessed by hand augering and test pitting, supplemented by test hole drilling, and geophysical surveys using hammer seismic equipment. The symbols for and locations of sample sites, test hole sites, and geophysical traverse lines are noted on Map 1.

Deposits with potential for further extractive development or those where existing data are scarce, are studied in greater detail. Representative layers in these deposits are sampled in 25- to 100-pound (11- to 45-kg) units from existing pit faces or from test pits. The samples are analysed for grain size distribution, and in some cases absorption, Los Angeles abrasion, and Magnesium Sulphate soundness tests and petrographic analyses are carried out. Analyses are performed either in the laboratories of the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation, or in the Geoscience Laboratories, Geoservices Section, Ontario Geological Survey.

The field data are supplemented by pit information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation. Data contained in these files include field estimates of the depth, composition, and "workability" of deposits, as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size, and depth of extraction of pits licenced under the Pits and Quarries Control Act are obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above-named groups in the compilation of inventory data is gratefully acknowledged.

Aerial photographs at various scales are used to determine the continuity of deposits, especially in areas where information is limited. Water well records, held by the Ontario Ministry of the Environment, are used in some areas to corroborate deposit thickness estimates or to indicate the presence of buried granular material. These records are used in conjunction with other evidence.

Topographic maps of the National Topographic System, at a scale of 1:50 000, are used as a com-

pilation base for the field and office data. The information is then transferred to a base map, also at a scale of 1:50 000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been established, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as test holes and water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot (0.3 m) thick layer of sand and gravel, one acre (0.4 ha) extent, assuming an average density of 110 pounds per cubic foot (1766 kg per cubic metre).

$$\text{Tonnage} = \text{Area} \times \text{Thickness} \times \text{Density Factor}$$

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of acres unavailable because of the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted (e.g. wayside and abandoned pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage (Column 7) presently available for extractive development and/or resource protection.

Reserve estimates are calculated for deposits of primary significance. Reserve estimates for deposits of secondary and tertiary significance are not calculated in Table 3, however the aggregate potential of these deposits is discussed in the report.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography

maps, and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated quarriable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of 60 feet (18 m) is used for thickness. Volume estimates are then multiplied by the density factor (the estimated weight in tons of a one-foot (0.3 m) thick section of rock, one acre (0.4 ha) in extent).

Resources of dolostone are calculated using a density factor of 165 pounds per cubic foot (2649 kg per cubic metre) or 3600 tons per acre (8070 tonnes per hectare). Sandstone resources are calculated using a density estimate of 146 pounds per cubic foot (2344 kg per cubic metre) and shale resources are calculated with a factor of 150 pounds per cubic foot (2408 kg per cubic metre).

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel deposits are termed possible resources (see Glossary, Appendix B) in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p.7) and with the Association of Professional Engineers of Ontario (1976).

Part II — Data Presentation and Interpretation

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources" shows the distribution of bedrock formations, the thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

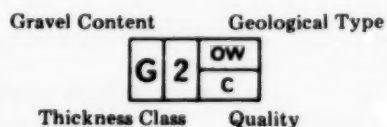
Map 1 is derived from existing surficial geology maps of the area or from aerial photograph interpretation in areas where surficial mapping is incomplete. The map shows the extent and quality of sand and gravel deposits within the study area and the present level of extractive activity.

On the map, gravel deposits are indicated by dark brown shading while sand deposits are shaded light brown. The present level of extractive activity is also indicated. Those areas which are licenced for extraction under the Pits and Quarries Control Act are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner/operator, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating on demand under authority of a permit) are identified by a numbered dot on Map 1 and described in Table 2. Similarly, test hole locations appear on Map 1 as a point symbol and are described in Table 7. Geophysics lines are shown on Map 1 by a line symbol and are interpreted in Table 8.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the map. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for every deposit shown on Map 1. These components are illustrated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate (greater than 4.75 mm) makes up less than 35 percent of the whole deposit. "G" indicates that the deposit contains more than 35 percent gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the deposit types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identifies the main quality limitations that may be present in the deposit as discussed in the next section.

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution of material sampled during field study. These symbols are derived from the information plotted on the aggregate grading curves found in the report. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically in the Texture Symbol by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30 percent gravel, 60 percent sand, and 10 percent silt and clay:



MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary; secondary; and tertiary. Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number which denotes its ranking order. All such deposits are shown by dark red shading on Map 2.

Deposits of secondary significance are not ranked numerically in this report, but are indicated by light red shading on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resources in the report area, they may contain large quantities of sand and gravel and should be considered as part of the aggregate supply of the area.

Areas of tertiary significance are outlined on the map by a solid line but have no shading. They are not considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

Selected Sand and Gravel Resource Areas of primary significance are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the report area is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

Deposit Size

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1 (greater than 20 feet (6 m) thick), and containing more than 35 percent gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

Aggregate Quality

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the deposit symbols on Map 1. They are: gravel content (G or S); fines (C); oversize (O); and lithology (L).

Three of the quality indicators deal with grain size distribution. The gravel content (G or S) indicates the suitability of aggregate for various uses. Deposits containing at least 35 percent gravel in addition to a minimum of 20 percent material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (high silt and clay content) may severely limit the potential use of a deposit. Fines content in excess of 10 percent may impede drainage in road sub-base aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent oversize material (greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so it must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

Another indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock types determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high quality uses such as concrete and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol shows either "C", "O", or "L" or any combination of these indicators, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt is made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations.

Quality data may also appear in Table 9, where the results of aggregate quality tests are listed by test type and sample location. The types of tests conducted and the test specifications are explained in Appendices B and E, respectively.

Analyses of unprocessed samples obtained from test holes, pits or sample sites are plotted on grain size distribution graphs. On the graphs are the Ontario Ministry of Transportation's gradation specification envelopes for aggregate products: Granular Base Course A, B and C; Hot-Laid Asphaltic Sand Nos. 1,2,3,4, and 8; and concrete sand. By plotting the gradation curves with respect to the specification

envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product. These graphs, called Aggregate Grading Curves, follow the tables in the report.

Location and Setting

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

The assessment of sand and gravel deposits with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report, but readers are encouraged to discuss them with personnel of the pertinent District Office of the Ontario Ministry of Natural Resources.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain roughly at the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalities with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on

geological data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, drift thickness and bedrock topography maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources) and from geotechnical test hole data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of these areas of thin drift are shown by three shades of blue. The darkest shade indicates where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas constitute potential resource areas because of their easy access. The medium shade indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these zones also represent potential resource areas. The lightest shade indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas, the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the report area. Those areas which are licenced for extraction under the Pits and Quarries Control Act are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner/operator, location, licenced acreage and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating on demand under authority of a permit) are also identified and numbered on Map 3 and described in Table 5. Two additional symbols may appear on the map. An open dot indicates the location of a selected water well which penetrates bedrock. The overburden thickness is shown in feet beside the open dot. Similarly, test hole locations appear as a point symbol with the depth to bedrock shown in feet beside it. The test holes may be further described in Table 7.

SELECTION CRITERIA

Criteria equivalent to those used for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario

Ministry of Transportation. The main characteristics and uses of the bedrock units found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource are usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of Bedrock Resource Areas has been restricted to a single level of significance. Three factors support this approach. First, quality and quantity

variations are gradual. Second, the areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material, and third, since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The Selected Areas, if present, are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Part III - Assessment of Aggregate Resources in Essa and Tosorontio Townships

LOCATION AND POPULATION

Essa and Tosorontio Townships occupy a combined area of 115,696 acres (46 822 ha) in south-central Simcoe County (Ontario Ministry of Municipal Affairs 1987). The townships are shown on portions of the Alliston (31 D/4), Barrie (31 D/5), Dundalk (41 A/1) and Collingwood (41 A/8) map sheets of the National Topographic System at a scale of 1:50 000. The townships are bounded by Sunnidale and Vespra Townships to the north, Adjala and Tecumseth Townships to the south, Innisfil Township to the east and Mulmur Township to the west. A substantial part of the map area is occupied by Canadian Forces Base Borden.

The population of the townships, exclusive of the town of Alliston and village of Cookstown, was 17,187 in 1985 (Ontario Ministry of Municipal Affairs 1987). Most of the residents are rural-farm or rural-residential inhabitants. Both townships have experienced substantial population increases. Figures from previous years indicate increases of 99 and 65 percent for Essa and Tosorontio Townships, respectively, between 1972 and 1985 (Ontario Ministry of Municipal Affairs 1987; Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1974). Such population growths can be expected to increase the demand for mineral aggregate to satisfy road-building and construction needs.

The town of Alliston, the village of Cookstown, and the settlement of Angus are the largest communities in the townships and serve as regional trade and retail centres. Smaller communities include Baxter, Lisle, Glencairn, Everett and Thornton. The city of Barrie is located to the northeast.

The townships are served by a grid of paved and gravel-surfaced roads. King's Highways 27, 89 and 90 serve as haulage routes to market centres. Lines of the Canadian National Railways and Canadian Pacific Railway serve Essa Township.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

Approximately 23 000 to 10 000 years ago, during the Great Ice Age (Late Wisconsin Substage of the Pleistocene Epoch), lobes or submasses of the Laurentide ice sheet advanced out of the Great Lakes basins and joined to entirely cover southern Ontario. The physiography and distribution of surficial materials in Essa and Tosorontio Townships, including the sand and gravel deposits shown on Map 1, are largely the result of repeated advances and the melting back of the margins of these glacial lobes.

The majority of Essa and Tosorontio Townships fall within two distinct physiographic regions: the Simcoe Lowlands and the Simcoe Uplands (Chapman and Putnam 1984). Within the townships the Simcoe Lowlands consist of three main sandy areas occurring below 750 feet (229 m) above sea level (a.s.l.). The Nottawasaga Basin is a flat, broad lacustrine sand plain extending in a north-south direction in Essa Township from Angus in the north to the community of Nicolston in the south. The Essa Flats, the second lowland area, is located adjacent to the con-

fluence of the Boyne and Nottawasaga Rivers. The sandy areas in the vicinity of the hamlets of Lisle and Tioga and the Canadian Forces Base Borden make up the third lowland which is referred to as the Camp Borden Sand Plain.

The second physiographic region, the Simcoe Uplands, rises some 200 to 300 feet (61 to 91 m) above the adjacent lake plains. In the northeastern part of Essa Township, deposits of ice-contact stratified drift and glaciofluvial outwash reach 1000 feet (305 m) a.s.l. in elevation. Another substantial highland area is found immediately south of Base Borden. A western extension of a third physiographic region, the Peterborough Drumlin Field (Chapman and Putnam 1984), is evident in a highland area located in the eastern third of Essa Township (Brinsmead 1973). The drumlins are streamlined, elongated hills oriented in a northeast-southwest direction. Pockets of sand and gravel are associated with drumlins and if these pockets are located they can be extracted for local use.

The highland areas are mainly underlain by till. An ice lobe originating in Georgian Bay advanced from the northwest and laid down the oldest of the three till units found in the townships. This material, informally named Allenwood till (Burwasser, in preparation), has been described as a sandy silt till, partly subdued by lacustrine action (Burwasser 1974d; Burwasser and Cairns 1974). The till is too fine grained for aggregate purposes.

A northern lobe advancing out of the Lake Simcoe basin deposited the Newmarket Till (Gwyn 1972a, b, c) which is a light yellowish-brown sand to compact silty sand till (Burwasser 1974a). Burwasser (1974d) suggests a correlation between this till and the Allenwood till. Newmarket Till makes up much of the highland areas in the townships. It has been used to produce a compact fill in the construction of bridge approaches in Essa Township (Hewitt and White 1969; White 1975).

The youngest till unit appears in both townships and consists of highly contorted laminated silty clay and clay (originally of glaciolacustrine origin) which contains grits and clay pebbles (Burwasser, in preparation). This till, referred to by Gwyn (1972c, 1975) as Kettleby Till, also constitutes much of the uplands in the townships. Kettleby Till is unsuitable as an aggregate source.

Intertill sediments associated with the various fluctuations of the Georgian Bay-Lake Simcoe ice lobe are present in both townships. Sporadic deposits of ice-contact stratified drift located in Essa Township were deposited along the ice margin by meltwaters flowing off the ice. In this area, the ice-contact features occur either as individual isolated bodies associated with ridges or as accumulations of silts and sands along valley sides (Deane 1950). The largest and most extensive of these features is located in the northeast part of Essa Township and extends into Innisfil Township. In the Innisfil Township portion of this deposit a number of pits have been opened, and pockets of crushable gravel have been extracted from one of the licenced properties.

Glaciofluvial outwash sediments were deposited in the area by sediment-laden meltwaters flowing away from the margins of the receding ice front. An extensive pitted outwash plain is located along the western boundary of Tosorontio Township and extends westward towards the Niagara Escarpment. The material in this plain consists predominantly of silty fine to medium sand with occasional bodies of pebbly sand (Gwyn 1972b; Gwyn and White 1973). A system of river terraces associated with the Pine River can be found incised into the outwash plain west of Everett, continuing into Mulmur Township. The terrace sediments were derived from the outwash plain and closely reflect its composition. A large outwash body northwest of Cookstown has been worked as a source of sandy gravel for many years. Most of the sandy outwash found in the report area is too silty to be of use in many road-building or construction applications and only fill related uses for this material should be considered.

A deposit of outwash gravel has been identified in the bed of a meltwater channel presently occupied by the Boyne River. This outwash gravel was deposited when meltwater rivers began cutting into older existing outwash and the meltwater flow became concentrated in the present broad valley of the Boyne River. As a result of this action, coarse granular material was redistributed and deposited along the river valley. The presence of relatively high proportions of sandstone and dolostone indicates that the source area for these outwash gravels was the Niagara Escarpment to the west where these particular lithologies are abundant (Gwyn 1972b). Pit faces in this deposit indicate that a veneer of sand masks the gravels. The coarse gravel and cobbles of the Boyne River outwash beds are unique and provide important granular resources suitable for pit-run material as well as Granular Base Course (G.B.C.) A.

Northwest of Glencairn a small area of outwash gravel associated with the Creemore outwash channel provides another source of good-quality aggregate. Here the gravels have been modified by subsequent aqueous erosion and are veneered by older alluvium (Burwasser 1974a).

With the final removal of the ice mass from the area, the waters of glacial Lake Algonquin inundated the lowland areas in the townships. The prolonged glaciolacustrine environment created the flat to gently rolling Simcoe Lowlands, occurring below 750 feet (229 m) a.s.l. The lake plain consists of silty fine-grained sand that covers much of the lowland's surface. The plain continues south into Tecumseth Township and northward into Sunnidale and Vespra Townships. Although much of this sand appears to be outwash in origin (Burwasser, in preparation, 1974d), it has been extensively reworked by the shallow waters of Lake Algonquin. The fine-grained silts and sands are subject to frost susceptibility and break-up, therefore limiting their potential as significant local aggregate resources.

The estuarine delta sand that surrounds Angus represents an older alluvial fan that was likely deposited into the Minesing pond as a minor delta (Burwasser, in preparation). The likelihood of locating coarse aggregate in this deposit is low.

The major shoreline bluffs of glacial Lake Algonquin in the townships occur at approximately 740 feet (226 m) a.s.l. At this elevation the associated beach, bar and spit deposits are the best sources of sand and gravel. Many pits have been developed in these deposits over the years particularly in northeast Essa Township, and presently some gravel bodies are near depletion. The material found in the beach deposits contains well rounded, fine to coarse gravel with interstratified medium to coarse sand. This material has been utilized for a full range of road-building and construction products.

The draining of Lake Algonquin marked the end of glacial activity in the area. Postglacial erosional and depositional processes have been of minor importance in changing the land surface in Essa and Tosorontio Townships. Isolated swamp deposits occur north of Thornton. Deposits of fine-grained alluvium are common in lowland areas such as the Notawasaga Basin where the river has cut into lacustrine sediments. There are also several wind-blown deposits. Alluvial and windblown deposits have very little aggregate use potential.

EXTRACTIVE ACTIVITY

At least thirty-eight sand and gravel pits have been established in Essa and Tosorontio Townships in the past. Many of these pits have been developed in high-quality glacial Lake Algonquin shoreline deposits. Other pits have been opened in glaciofluvial outwash deposits, glaciolacustrine sands and in ice-contact stratified drift deposits.

Many of the pits became inactive in 1975 when Essa and Tosorontio Townships were designated under the Pits and Quarries Control Act, although some pits have become "depleted" of crushable gravel. At the time of writing, records on file with the Huronia District Office of the Ontario Ministry of Natural Resources indicate that thirteen sand and gravel pits were licenced for extraction. The total area licenced for extraction in the townships is 474.11 acres (191.87 ha). One property is presently rehabilitated (pit no. 8). Records of the total production from all licenced sources in Essa and Tosorontio Townships show that the combined average annual production over the seven-year period from 1975 to 1981 was 164,000 tons (149 000 tonnes).

Several of the sources located in the glaciofluvial and glaciolacustrine deposits possess a "moderate to high" use rating according to criteria established by the Ontario Ministry of Transportation (Deike 1982). Many of the sources have been capable of producing high-quality coarse aggregate. Pit nos. 2, 3, and 4 contain crushable material and are able to supply materials for G.B.C. A and other lesser quality products. Selective processing must be employed for the production of binder course pavement mixes such as Hot-Laid (H.L.) Nos. 4 and 8.

SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 1 illustrates the distribution of sand and gravel deposits in Essa and Tosorontio Townships. The total area occupied by these deposits is approximately

54,000 acres (21 900 ha), or 47 percent of the total area of the townships. The deposits contain possible resources of 2700 million tons (2450 million tonnes). However, much of the fine-grained deposits included in the calculations have very limited potential for use as road-building or construction aggregate.

Map 2 illustrates the Selected Sand and Gravel Resource Areas of primary, as well as of secondary and tertiary significance. Large amounts of good-quality coarse aggregate are available at or near the surface in a glaciofluvial outwash deposit centred in the Boyne River valley. Sand and gravel extracted from licenced sources in this deposit have been extensively used for a wide range of aggregate products including G.B.C. A. A nearly continuous band of glacial Lake Algonquin beach deposits is located in north-central Essa Township. In the past, many of the pits developed in these deposits also had been able to supply high-quality aggregate.

The Selected Sand and Gravel Resource Areas of Primary Significance occupy a total available area of 1740 acres (700 ha), and contain possible resources of approximately 52 million tons (47 million tonnes). The parts of the selected areas which are available for extraction represent 3 percent of the total area occupied by sand and gravel deposits in the townships and 2 percent of the original tonnage.

All of the remaining glaciolacustrine beach deposits and ice-contact stratified drift deposits, and two glaciofluvial outwash sand deposits, have been selected at the secondary level of significance. These deposits are not the "best" resources, however, they should be considered as they may have strategic local value.

SELECTED SAND AND GRAVEL RESOURCE AREA 1

Selected Sand and Gravel Resource Area 1 constitutes the largest and most important sand and gravel deposit in Essa and Tosorontio Townships. This deposit is concentrated in the meltwater channel presently occupied by the Boyne River. Area 1 consists of outwash gravels that are covered by a veneer of sand. The geological boundary for these gravels is somewhat generalized because of the limited amount of subsurface data, and has been based primarily on work completed by Deike (1982) and Gwyn (1972b).

Four properties are currently licenced to operate in the resource area (pit nos. 2, 3, 4, and 5). One unlicenced pit (pit no. 14) has also operated in the Area. The water table is approximately 5 to 9 feet (1.5 to 3 m) below the surface and dragline operations have been carried out in pit nos. 3 and 4. Pit faces range in height from 3 to 15 feet (1 to 5 m) and dragline depths range between 7 and 12 feet (2 and 4 m) below the water table. Faces in the pits and stockpiled dragline material consist of fine to medium sand and well rounded fine to coarse gravel. Over-size material was noted in most properties. Gravel content ranged from 30 to 70 percent. A sample from pit no. 3 revealed 54 percent gravel (Figure 2a). Test holes completed by the Ministry of Transportation in pit nos. 2 and 4 revealed approximately 10 to 15 feet (3 to 5 m) of coarse granular material before encountering glacial till (Deike 1982). A geophysics traverse

line (TO-GT-1) completed on the floor of pit no. 2 (Map 1) confirmed the presence of an additional 8 feet (2 m) of sand and gravel before encountering till (Table 8). Selected water well data indicates a considerable depth of sand and gravel.

Aggregate suitability data obtained from the Ministry of Transportation indicate that this deposit is a source of high-quality aggregate acceptable for a wide range of products if suitable processing and quality control techniques are employed. Pit nos. 2, 3, 4 and 14 have been given a "moderate to high" pit use rating (Deike 1982). Products from these sources include G.B.C. A, B and C, 16 mm Crushed A and B and many hot-laid sand products, provided blending is used to alter the grain size distribution. The over-size fraction must be either removed or crushed for the production of G.B.C. B and C for pit nos. 2 and 4, respectively. Pit no. 4 is able to produce H.L. 4 asphaltic aggregate and pit no. 14 has produced both H.L. 4 and 8 stone.

Gravel quality and durability in the Boyne River deposit are variable. Siltstone is a major deleterious constituent in the coarse outwash gravels (Deike 1982). The siltstone may originate from shaly beds that occur in the underlying Ordovician bedrock. Because of its character, siltstone causes rapid surface deterioration of asphalt (Deike 1982). Careful selection and production testing would be necessary to keep the siltstone content to a minimum if the gravels were to be considered for use in binder course pavements. The gravels are not suitable for high-quality surfacing aggregate (Deike 1982). Siltstone can be removed by a beneficiation process to improve the aggregate quality, however these procedures are very costly and are usually restricted to large-scale operations.

Petrographic examinations of the coarse aggregate quality from pit nos. 2, 3 and 4 revealed numbers ranging from acceptable figures of 125 and 135 to values in excess of 200. Magnesium sulphate soundness tests conducted on fine and coarse aggregate from the licenced pits also indicate a wide range of readings. Magnesium sulphate losses of 16.6 percent obtained from one tested sample from pit no. 2 reflects the presence of siltstone clasts (Deike 1982). Results from the Los Angeles abrasion test for hardness, toughness and durability conducted on coarse aggregate samples from two sources indicate acceptable percentage loss readings.

Area 1 occupies 1800 acres (730 ha), exclusive of the licenced properties. Cultural constraints and previous extraction reduce the area presently available to 1140 acres (460 ha). Based on Ministry of Transportation test hole depths, the Boyne River outwash spillway has been estimated to have an average depth of approximately 10 feet (3 m). Therefore, the sand and gravel resources total approximately 28 million tons (25 million tonnes). The resource area is located close to King's Highway 89 which intersects King's Highway 27 at Cookstown. Apart from the deleterious siltstone occurrences, Area 1 is of considerable importance as a regional source of road-building and construction materials.

SELECTED SAND AND GRAVEL RESOURCE AREAS 2a AND 2b

Selected Sand and Gravel Resource Areas 2a and 2b consist of glaciolacustrine beach deposits related to the abandoned shorelines of glacial Lake Algonquin. The resource areas are found in the north-central part of Essa Township at an elevation of 740 feet (226 m) a.s.l. There has been a substantial history of sand and gravel extraction from these deposits over the past years. Many of the sources are presently depleted of gravel, and sand now predominates.

Ten unlicensed pits have been identified within the resource areas (pit nos. 21 to 23, 28, 29, 34 to 38). Pit faces range in height from 5 to 30 feet (1.5 to 9 m) and expose variable gravel contents ranging from 20 to 50 percent. Faces in pit nos. 22, 28, 29 and 35 generally expose well rounded, fine to coarse gravel with interstratified medium to coarse sand. During field investigation fresh excavations made in the southern face of pit no. 35 revealed well sorted interlayers of open worked granules with common imbricated shingle layers. A sample of the aggregate from this southern face contained 52 percent gravel (Figure 4a).

Aggregate suitability data obtained from the Ministry of Transportation indicate that in the past aggregate from pit nos. 22, 23 and 29 was acceptable for G.B.C. A, B and C, 16 mm Crushed Type A and B and H.L. 4 asphaltic aggregate. Sand control is required for the production of G.B.C. A in pit no. 29 and the sand grades slightly too coarse for hot-laid products and blending is recommended. The grain size distribution for the sample taken from pit no. 35 lies within acceptable limits for a wide range of granular base course products and should be suitable for some higher specification fine aggregate products (Figures 4a and 4b).

Resource Areas 2a and 2b occupy 1040 acres (420 ha). Cultural constraints and previously extracted areas reduce the available area to 560 acres (227 ha). Based on pit face heights and selected water well data, the average thicknesses of usable materials in Areas 2a and 2b are estimated to be 20 and 15 feet (6 and 5 m), respectively. Therefore, the sand and gravel resources total 23 million tons (21 million tonnes). King's Highway 90 and two spur lines of the Canadian National Railways cross through Area 2a.

SELECTED SAND AND GRAVEL RESOURCE AREA 3

Selected Sand and Gravel Resource Area 3 is made up of three glaciofluvial outwash gravel deposits, one buried by a thin veneer of older alluvium and another slightly modified by subsequent aqueous erosion (Burwasser, in preparation, 1974a). The resource area is located in the northwestern corner of Tosorontio Township near Glencairn. The deposits extend northward into Sunnidale and Nottawasaga Townships and form part of the extensive Creemore channel outwash (Burwasser, in preparation). An overgrown pit developed in the modified portion of the outwash in Sunnidale Township exhibits a 10-foot (3 m) face of stratified, clean, medium to coarse sand and well rounded, fine aggregate. A sample of the material taken from the pit revealed more than a 50 percent gravel content. Gradations performed on the material

indicate that it is suitable for a wide range of granular base course products and a number of high-specification hot-laid sand uses.

Resource Area 3 occupies 40 acres (16 ha). Deletions for cultural constraints leave 30 acres (12 ha) currently available for extraction. Based on a conservative depth estimate of 10 feet (3 m), sand and gravel resources are estimated to be 1 million tons (1 million tonnes).

SAND AND GRAVEL RESOURCE AREAS OF SECONDARY SIGNIFICANCE

The remainder of the glaciolacustrine beach deposits and all of the ice-contact stratified drift deposits located in Essa Township have been selected at the secondary level of significance. Two areas of glaciofluvial outwash located in the eastern part of the report area have also been selected. The secondary deposits provide alternate extractive sites to supplement those provided by the primary areas.

Three licensed properties (pit nos. 10, 11 and 12) and three unlicensed pits (pit nos. 17, 26 and 33) have been developed in the secondary beach deposits in Essa Township. Many of these sources are overgrown, and some are water filled or depleted. In places, the sources expose well rounded, fine to coarse gravel with interstratified medium to coarse sand. Faces range in height from 5 to 25 feet (1.5 to 8 m) and expose maximum gravel contents of 30 percent. Data from the Ministry of Transportation indicate that the aggregate from pit nos. 12 and 17 has been used for the production of G.B.C. A, B and C, and for H.L. 4 stone. The sand grades variable for hot-laid products.

Two extensive areas of glaciofluvial outwash are located northwest of Cookstown and north of Thornton. Four licensed properties (pit nos. 6, 7, 8 and 9) and one unlicensed pit (pit no. 19) have been developed in the larger deposit northwest of Cookstown. This deposit has been extensively worked for sand and gravelly sand. Face heights range between 10 to 30 feet (3 to 9 m) and expose low gravel contents. A sample taken from pit no. 9 indicates that the gravel content is less than 20 percent (Figure 2a). The aggregate in the sample is generally acceptable for select subgrade material and G.B.C. B and C. Based on gradation, the sand is suitable for most high-specification fine aggregate products such as concrete and asphalt sand (Figure 2b).

The outwash deposit located north of Thornton is part of a larger deposit that extends eastward into Innisfil Township. The outwash was deposited on a rolling till plain and is variable in thickness (Deane 1950). Licensed pit no. 13 is the only source developed in this deposit in Essa Township and contains moderate reserves of gravel and sandy gravel (Brinsmead 1973). The southern face of the property reveals approximately 5 to 10 feet (1.5 to 3 m) of well rounded and well stratified, fine to coarse gravel and medium to coarse sand. Gravel contents in the southern face range between 40 and 50 percent, while in the northern face they drop to less than 10 percent. A sample taken from the south face contained 47 percent gravel (Figure 3a). Gradations performed on this sample indicate that the material is generally suitable

for a wide range of granular base coarse products (Figure 3a). The sand is suitable for some asphalt sand products but, as it grades fine for concrete sand, excessive fines are recommended for removal (Figure 3b). The gravel exposed in the southern face appears to be concentrated near the surface. A test hole (TO-TH-1) revealed a 14-foot (4 m) depth of clean fine sand beneath the pit floor (Table 7; Figures 3a and 3b). Samples of the aggregate from the test hole contained approximately 97 percent sand and less than 1 percent gravel. The grain size distribution for TO-TH-1 is borderline for G.B.C. C and is too fine for high-specification fine aggregates (Figures 3a and 3b). A geophysics traverse line (TO-GT-3) completed in the southern face confirmed the presence of approximately 6 feet (2 m) of sand and gravel overlying 23 feet (7 m) of wet sand (Table 8).

All of the ice-contact stratified drift deposits that occur in Essa Township have also been selected at the secondary level. Three of the deposits are north of Alliston, while the remaining three are located northeast of Ivy. Faces in pit nos. 31 and 32 expose fine to medium sand, however, a pocket of angular, fine to coarse gravel is located in the western face of pit no. 32 and reveals up to 30 percent gravel. Water well information indicates that considerable depths of sandy material occur in the large ice-contact deposit extending eastward into Innisfil Township. A licenced property developed in this material, in Innisfil Township, reveals pockets of crushable gravel within the sandy aggregate. A test hole in the Innisfil Township portion of the deposit revealed 20 feet (6 m) of fine to medium sand beneath the pit floor, indicating that the gravel may be concentrated at the surface. Samples taken from the gravel pockets were found to contain 37 percent gravel and 63 percent sand (Ontario Geological Survey, in preparation).

SAND AND GRAVEL RESOURCE AREAS OF TERTIARY SIGNIFICANCE

Good potential exists for finding additional sources of outwash gravel along river valleys in Tosorontio Township. An unlicensed pit (pit no. 15) located along the Pine River, north of the community of Everett, exhibits a 10- to 15-foot (3 to 5 m) face of well rounded, fine to coarse outwash-type gravel and medium to coarse sand. In places, the estimated gravel content reached 35 percent.

Although mapped as glaciolacustrine sand, the southern face of licenced pit no. 1 exposes well rounded fine aggregate with clean medium to coarse sand. Gravel contents are variable within the pit and in the southern face they range between 20 and 30 percent. Water well data in the immediate vicinity of Glencairn also indicate the presence of sand and gravel.

Additional field work including a subsurface investigation is required to identify additional areas of high potential for extractive development. If further subsurface studies reveal the presence of coarse material, those areas may possess future value as a source of crushable material suitable for G.B.C. A and a number of pit-run uses. Unfortunately, such deposits of coarse aggregate may be buried under a

variable thickness of lacustrine or glaciofluvial sand (Gwyn 1972b).

BEDROCK GEOLOGY

Essa and Tosorontio Townships are underlain by a succession of Middle and Upper Ordovician strata of the Verulam, Lindsay, Blue Mountain and Georgian Bay Formations. These units are exposed in sequence from the oldest in the northeast corner of the map area, to the youngest in the southwest.

The oldest bedrock unit in the report area is the Verulam Formation which occurs in the northern part of Essa Township. The formation consists of approximately 200 feet (61 m) of fossiliferous, pure to impure grey limestone, interbedded with thin to thick shale layers (Liberty 1969). This unit has been quarried in other parts of Ontario to produce cement. However, the formation is not well suited for the production of crushed stone products because of low abrasion and freeze-thaw resistance and the presence of shaly interbeds (Dolar-Mantuani 1975).

The Lindsay Formation overlies the Verulam Formation and occupies a large area in northern Tosorontio Township and southern Essa Township. The formation consists of two members: the lower member of grey argillaceous limestone containing numerous shaly partings, particularly in the upper portion of the unit; and the Collingwood Member (Russell and Telford 1983) of brownish-black, organic-rich, inter-bedded calcareous shale and limestone. The lower member has been quarried at Picton, Ogden Point and Bowmanville for use as a raw material in cement production. The rock from the lower member is soft and nonresistant to weathering, and contains numerous clayey partings. The formation is generally unsatisfactory for use as concrete aggregate and probably also for less demanding aggregate uses (Dolar-Mantuani 1975). Testing would be required to determine the quality of the Lindsay Formation in the township for use in the production of aggregate.

Shale of the Blue Mountain Formation occurs in a continuous band across Tosorontio Township to the town of Alliston. The unit overlies the Lindsay Formation and consists of blue-grey noncalcareous shale. This formation is generally not suitable for the production of concrete aggregate. Its value as expanded aggregate has not yet been determined (Guillet 1977).

The thin-bedded Georgian Bay Formation consists of siltstones, shaly limestones and shales. It is the youngest bedrock unit in the report area and occupies the southwest corner of Tosorontio Township. Here, approximately 4300 acres (1740 ha) are covered by less than 50 feet (15 m) of drift as indicated by selected water well data. This unit has been used extensively for brick manufacture in the Toronto area and the rock has been used for some forms of heat-expanded lightweight aggregate in the past (Guillet 1977). However, it has little value for load-bearing uses such as road aggregate. Because of the present limited demand for this unit and the presence of better exposures elsewhere, the Georgian Bay Formation has not been selected for resource protection.

The bedrock topography is generally flat and the formations possess a gentle dip ranging from 20 to 40 feet per mile (4 to 8 metres per kilometre) in a southwesterly direction (Burwasser 1974a; Liberty 1969). Overburden thickness in most of the report area generally exceeds 50 feet (15 m). One water well located north of the town of Alliston indicates a depth of 536 feet (163 m) to bedrock. Quarrying of these units, therefore, is not practical.

SUMMARY

The sand and gravel deposits of Essa and Tosorontio Townships are the product of glacial activity that took place during the Great Ice Age. Presently, the reserves of granular materials in Essa Township are thought to be adequate to supply local road-maintenance requirements. Two glacial Lake Algonquin beach deposits located in the north-central part of the township have been selected for possible resource protection and/or development at the primary level of significance. In the past, these deposits were capable of supplying good-quality coarse aggregate.

Coarse granular deposits in Tosorontio Township are also scarce. The largest gravel deposit is confined to the Boyne River valley in the southwestern part of the township. This deposit is capable of producing a number of valuable aggregate products such as G.B.C. A and has been selected at the

primary level of significance. The sporadic occurrence of siltstone, however, necessitates the need for careful quality control for the production of binder course paving aggregate.

In addition, a number of the remaining beach, outwash and ice-contact deposits in Essa Township have been selected as secondary deposits. These deposits should be considered as part of the total aggregate supply.

Bedrock units underlying Essa and Tosorontio Townships include the Verulam, Lindsay, Blue Mountain and Georgian Bay Formations. Thick drift restricts most of the formations from being selected for possible resource protection.

Enquiries regarding the Aggregate Resources Inventory of Essa and Tosorontio Townships should be directed to the Aggregate Assessment Office, Engineering and Terrain Geology Section, Ontario Geological Survey, Mines and Minerals Division, Ontario Ministry of Northern Development and Mines, Room M1B-45, Macdonald Block, Queen's Park, Toronto, Ontario, M7A 1W4 [Tel. (416) 965-1663], or to the Resident Geologist, Mines and Minerals Division, Ministry of Northern Development and Mines, Box 5463, 659 Exeter Road, London, Ontario, N6A 4L6 [Tel. (519) 661-2773], or to the Ontario Ministry of Natural Resources at the Huronia District Office, Midhurst, Ontario, L0L 1X0 [Tel. (705) 728-2900].

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, ESSA AND TOSORONTIO TOWNSHIPS.*

1	2	3	4	1	2	3	4
Class No.	Deposit Type (see Appendix C)	Areal Extent Acres (Hectares)	Original Tonnage Millions of Tons (Tonnes)	Class No.	Deposit Type (see Appendix C)	Areal Extent Acres (Hectares)	Original Tonnage Millions of Tons (Tonnes)
1	G-LB	440 (178)	22 (20)				
	S-IC	770 (310)	48 (44)	2	G-LB	600 (243)	22 (20)
	S-OW	17,600 (7100)	1320 (1200)		G-OW	2030 (820)	51 (46)
					G-OW (buried)	25 (10)	1 (1)
					S-LB	425 (172)	16 (14)
					S-LD	1350 (550)	51 (46)
					S-LP	29,500 (11 900)	1110 (1010)
					S-OW	1140 (460)	43 (39)
				4	S-WD	100 (40)	1 (1)
						54,000 (21 900)	2700 (2450)

*Identified deposit areas within Earl Rowe Provincial Park, the town of Alliston, the village of Cookstown and Canadian Forces Base Borden have been omitted on all tables.

N.B. Minor variations in all tables are caused by rounding of data.

TABLE 2. SAND AND GRAVEL PITS, ESSA AND TOSORONTIO TOWNSHIPS.

1 No.	2 Ministry of Trans- portation No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas	7 Face Height	8 % Gravel
					Acres (Hectares)	Feet (Metres)	
LICENCED PITS							
Tosorontio Township							
1	C11-108	Stephens Brothers	W1/2 33	2	50.82 (20.57)	10-15 (3-5)	variable; 20-30 s. face
2	A04-012	Township of Tecumseth	E1/2 6&7	2	31.5 (12.8)	3-5 (1-1.5)	40-70
3	A04-013	John Patton	E1/2 7	3	86.0 (34.8)	10 (3) 7-8 (2)	40-70 (old face) dragline operation (below water table)
4	A04-009	A.G. Cook	W1/2 7	4	60.0 (24.3)	10 (3) 7-12 (2-4)	40-70 (old face) dragline operation (below water table)
5	-	Township of Tosorontio	7	4	35.8 (14.5)	10-15 (3-5)	40-70 (below water table)
Essa Township							
6	A04-026	Elwood Wright	E1/2 4	7	11.96 (4.84)	10-25 (3-8)	<20
7	A04-147	Elwood Wright	W1/2 5	8	28.27 (11.44)	10-15 (3-5)	<10 (variable)
8	-	M.J. Bowes	W1/2 5	8	4.08 (1.65)	10 (3)	- (rehabili- tated)
9	A04-024	Harry Ross	W1/2 4	9	49.3 (20.0)	10-25 (3-8)	10-20 (variable)
10	B03-175	Russel Patterson Burbidge	W1/2 19	4	20.98 (8.49)	5-10 (1.5-3)	<20 (partially overgrown and largely depleted)
11	B03-191	271887 Ontario Inc.	W1/2 31	7	32.1 (13.0)	-	- (water filled)
12	B03-148 B03-187	Edmond Bernard Roth Const.	NE1/4 27	9	47.15 (19.08)	5-25 (1.5-8)	<10 (variable in sections)

TABLE 2. SAND AND GRAVEL PITS, ESSA AND TOSORONTIO TOWNSHIPS.

1 No.	2 Ministry of Transportation No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas	7 Face Height	8 % Gravel
					Acres (Hectares)	Feet (Metres)	
13	B03-173	John Ellis Const. Ltd.	S1/2 24	11	16.15 (6.54) <u>474.11</u> (191.87)	5-10 (1.5-3)	40-50 S.face <10 N.face
UNLICENCED PITS*							
Tosorontio Township							
14	A04-014	Ministry of Transportation (E. Brett)	5	1		10-15 (3-5)	30-40 (partially overgrown)
15	-	Burnes Wales	13	4		10-15 (3-5)	35 (variable)
16	-	Unknown	11&12	7		10-20 (3-6)	20 (variable and partially overgrown)
Essa Township							
17	A04-028	Dunn-Coulter	2	5		10-20 (3-6)	<20-30 (largely overgrown)
18	-	Unknown	4	5		20-40 (6-12)	0
19	-	Unknown	2&3	9		10-30 (3-9)	20-30 (partially overgrown)
20	-	Unknown	11	9		20-30 (6-9)	- (overgrown)
21	-	Unknown	15	7		20-30 (6-9)	- (rehabili- tated)
22	B03-055	Essa Township	16	6		5-10 (1.5-3)	<30 (south face)
23	B03-145	Henry E. Davis	19	6		10 (3)	30-40 (partially overgrown)
24	B03-176	Mooney Pit	18	5		5-10 (1.5-3)	<10
25	-	Unknown	20	5		5-10 (1.5-3)	0 (dune feature)
26	-	Glasman	21	4		5 (1.5)	20-30 (overgrown and water filled)

*Abandoned pits or wayside pits operating on demand under authority of a permit.

TABLE 2. SAND AND GRAVEL PITS, ESSA AND TOSORONTIO TOWNSHIPS.

1 No.	2 Ministry of Transportation No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas	7 Face Height		8 % Gravel
						Acres (Hectares)	Feet (Metres)	
27	-	Unknown	23	7			10-15 (3-5)	0 (overgrown)
28	B03-25	Coxworth	23	7			5-15 (1.5-5)	30 (variable and partially overgrown)
29	B03-026	Banting	23	7			5-15 (1.5-5)	30 (variable and partially overgrown)
30	-	Unknown	28	3			5 (1.5)	<5 (overgrown, dune feature)
31	-	Unknown	25	9			10-50 (3-15)	<10 (variable and partially overgrown)
32	-	Unknown	26	9			10-25 (3-8)	20-30 (partially overgrown)
33	B03-124	Essa Township	28	9			5-10 (1.5-3)	(water filled and overgrown)
34	B03-127	Ford (A.G. Cook)	32	7			10-15 (3-5)	(overgrown and water filled)
35	-	Essa Township	32	8			15-20 (5-6)	30-50 (south face)
36	B03-096	Crowe	31&32	8			10-15 (3-5)	20-40 (variable and over- grown)
37	B03-180	Ontario Hydro	31&32	8			10-20 (3-6)	- (largely depleted and water filled)
38	-	C.N.R.	32	8			10-20 (3-6)	- (overgrown and water filled, depleted)

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, ESSA AND TOSORONTIO TOWNSHIPS.

1 Deposit No.	2 Unlicenced Area Acres (Hectares)	3 Cultural Setbacks Acres (Hectares)	4 Extracted Area Acres (Hectares)	5 Available Area Acres (Hectares)	6 Estimated Deposit Thickness Feet (Metres)	7 Available Aggregate Millions of Tons (Tonnes)
1	1800 (730)	650 (265)	10 (4)	1140 (460)	10 (3)	28 (25)
2a	440 (178)	230 (93)	65 (26)	145 (59)	20 (6)	7 (6)
2b	600 (243)	120 (49)	60 (24)	420 (170)	15 (5)	16 (14)
	<u>1040</u> (420)	<u>350</u> (142)	<u>125</u> (51)	<u>560</u> (227)		<u>23</u> (21)
3	40 (16)	10 (4)	0 (0)	30 (12)	10 (3)	1 (1)
	<u>2900</u> (1170)	<u>1010</u> (410)	<u>135</u> (55)	<u>1740</u> (700)		<u>52</u> (47)

TABLE 4. TOTAL IDENTIFIED BEDROCK RESOURCES, ESSA AND TOSORONTIO TOWNSHIPS.

1 DRIFT THICKNESS Feet (Metres)	2 FORMATION	3 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	4 AREAL EXTENT Acres (Hectares)	5 ORIGINAL TONNAGE Millions of Tons (Tonnes)
3-25 (1-8)	Georgian Bay Formation	60 (18)	100 (40)	19 (17)
25-50 (8-15)	Georgian Bay Formation	60 (18)	4200 (1700)	810 (740)
			<u>4300</u> (1740)	<u>830</u> (750)

TABLE 5. QUARRIES, ESSA AND TOSORONTIO TOWNSHIPS.

1 NO.	2 MINISTRY OF TRANS- PORTATION NO.	3 OWNER/ OPERATOR	4 LOT	5 CON.	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)
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-NONE-

TABLE 6. SELECTED BEDROCK RESOURCE AREAS, ESSA AND TOSORONTIO TOWNSHIPS.

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 UNLICENCED AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED WORKABLE THICKNESS Feet (Metres)	8 AVAILABLE RESOURCES Millions of Tons (Tonnes)
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-NONE-

TABLE 7. SUMMARY OF TEST HOLE DATA, ESSA AND TOSORONTIO TOWNSHIPS.

ESSA TOWNSHIP**Test Hole Number:** TO-TH-1**Location:** Lot 24, Conc. 11, in floor of pit no. 13**Elevation:** Approximately 1000 feet (305 m) a.s.l.**Date:** November 9, 1982

Depth feet (metres)	Description
0-5 (0-1.5)	clean fine sand
5-8 (1.5-2)	fine sand
8-11 (2-3)	clean fine sand
11-14 (3-4)	fine sand; terminated test hole after encountering water at approximately 14 feet (4 m)

Test Hole Number: TO-TH-2**Location:** Lot 25, Conc. 11, north of TO-TH-1 in farm
field**Elevation:** Approximately 900 feet (274 m) a.s.l.**Date:** November 9, 1982

Depth feet (metres)	Description
0-3 (0-1)	compact sandy silty till; hole terminated at 3 feet (1 m)

TABLE 8. SUMMARY OF GEOPHYSICS DATA, ESSA AND TOSORONTIO TOWNSHIPS.

TOSORONTIO TOWNSHIP**Line Number:** TO-GT-1**Line Direction:** 90° (East to West)**Method:** Hammer Seismic**Location:** Lots 6 and 7, Conc. 2 (on floor of pit no. 2)**Elevation:** Approximately 775 to 800 feet (236 to 244 m) a.s.l.**Geology:** Sand overlying glaciofluvial outwash gravel**Seismic Data:**

Number of Layers: 1

Layer Velocity: $V_1 = 1600$ ft./sec. (490 m/sec.) $V_2 = 6000$ ft./sec. (1830 m/sec.)Layer Thickness: $D_1 = 7.6$ feet (2.3 m)**Interpretation:**

Layer 1: Approximately 8 feet (2 m) of sand and gravel (confirmed by pit face)

Layer 2: Water encountered at approximately 8 feet (2 m) overlying glacial till (confirmed by Ministry of Transportation test hole in property)

ESSA TOWNSHIP**Line Number:** TO-GT-2**Line Direction:** 90° (East to West)**Method:** Hammer Seismic**Location:** Lot 15, Conc. 6 (completed in Simcoe County Reforestation Area)**Elevation:** Approximately 725 to 750 feet (221 to 229 m) a.s.l.**Geology:** Southern extension of Lake Algonquin glaciolacustrine beach deposit**Seismic Data:**

Number of Layers: 1

Layer Velocity: $V_1 = 1250$ ft./sec. (380 m/sec.)Layer Thickness: $D_1 = 33$ feet (10 m) (if minimum depth analysis is utilized)**Interpretation:**

Layer 1: Approximately 30 to 35 feet (9 to 11 m) of sand and gravel

Line Number: TO-GT-3**Line Direction:** 90° (East to West)**Method:** Hammer Seismic**Location:** S 1/2 Lot 24, Conc. 11 (completed in south face of pit no. 13)**Elevation:** Approximately 1000 feet (305 m) a.s.l.**Geology:** Mapped as outwash sand with some gravel present at surface**Seismic Data:**

Number of Layers: 3

Layer Velocity: $V_1 = 1200$ ft./sec. (365 m/sec.) $V_2 = 3500$ ft./sec. (1070 m/sec.) $V_3 = 7300$ ft./sec. (2220 m/sec.)Layer Thickness: $D_1 = 5.6$ feet (1.7 m) $D_2 = 23.0$ feet (7 m)**Interpretation:**

Layer 1: Approximately 6 feet (2 m) sand and gravel (confirmed by south face of property)

Layer 2: Approximately 23 feet (7 m) wet sand (confirmed by drilling, TO-TH-1)

Layer 3: Consolidated material (till)

TABLE 9. AGGREGATE QUALITY TEST DATA, ESSA AND TOSORONTIO TOWNSHIPS.

-NONE-

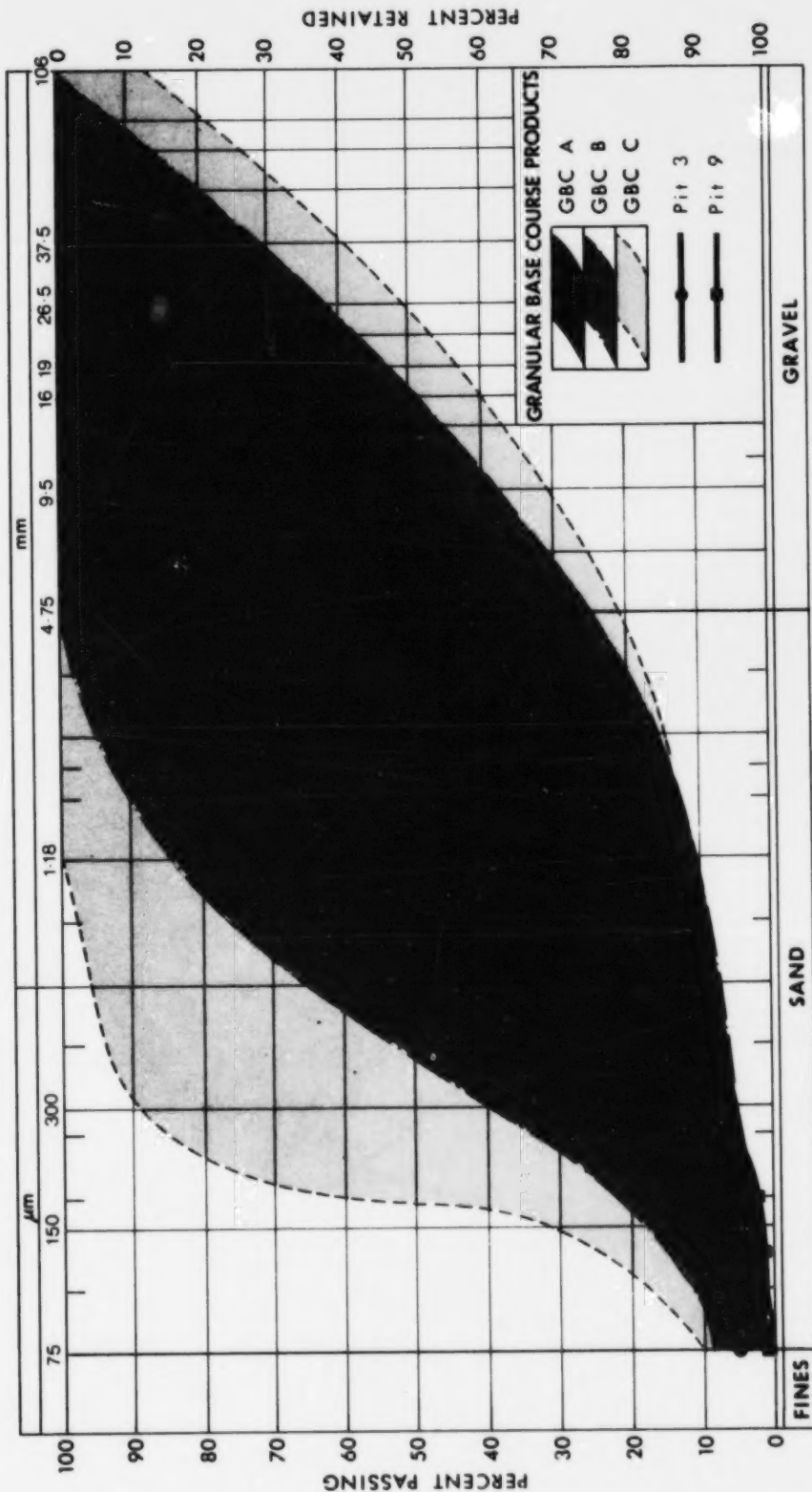


FIGURE 2a: AGGREGATE GRADING CURVES, TOSORONTIO TOWNSHIP;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

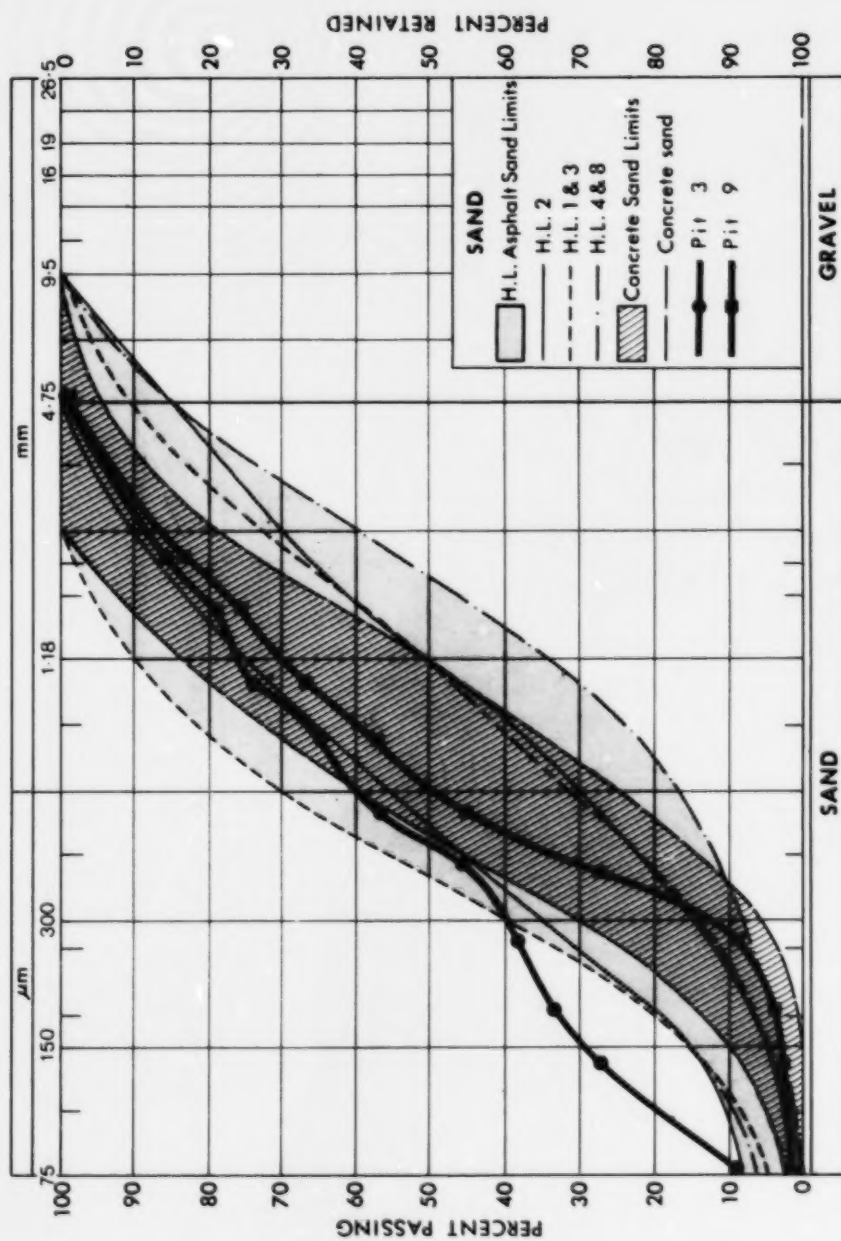
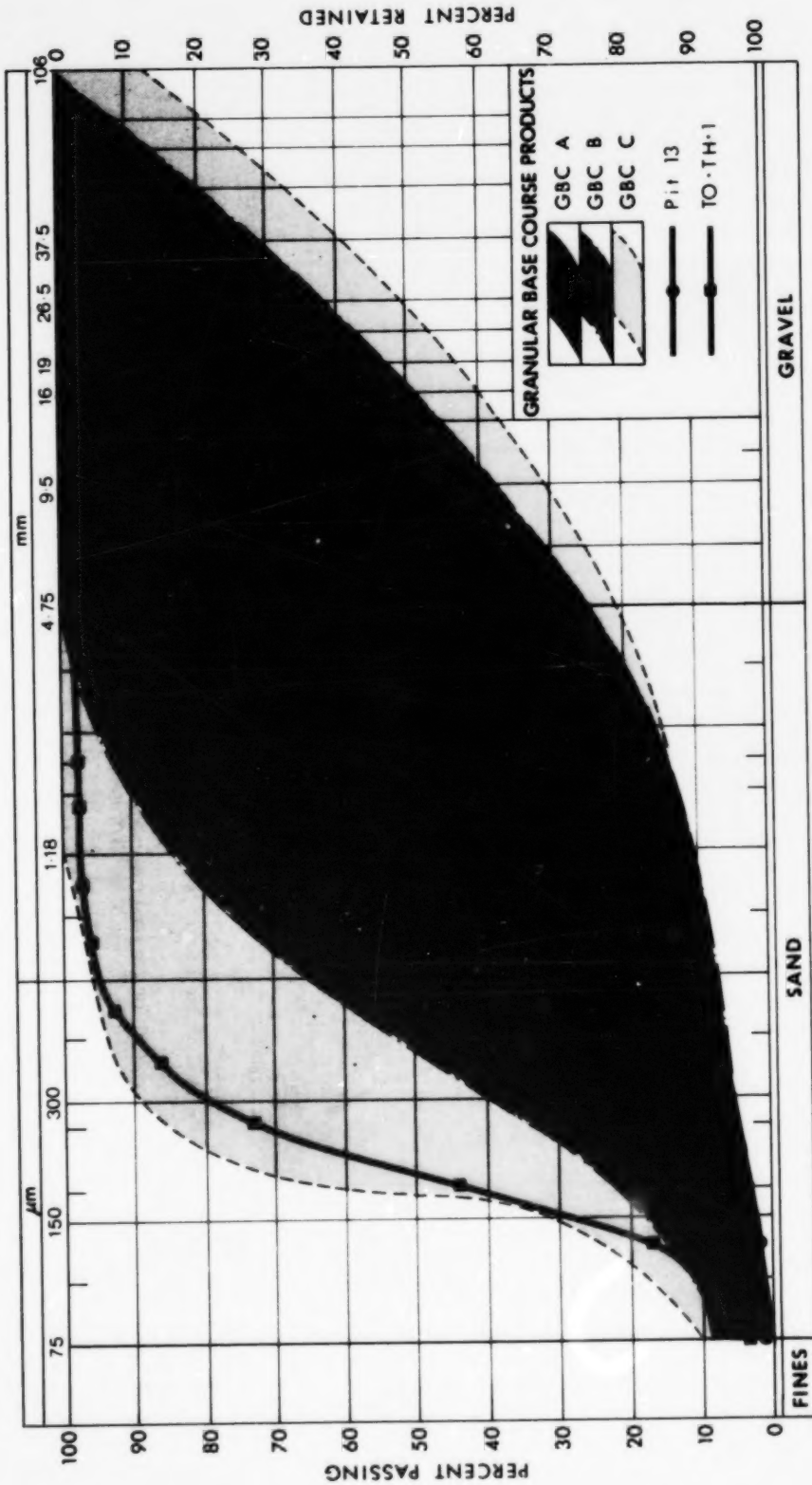


FIGURE 2b: AGGREGATE GRADING CURVES, TOSORONTIO TOWNSHIP;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.



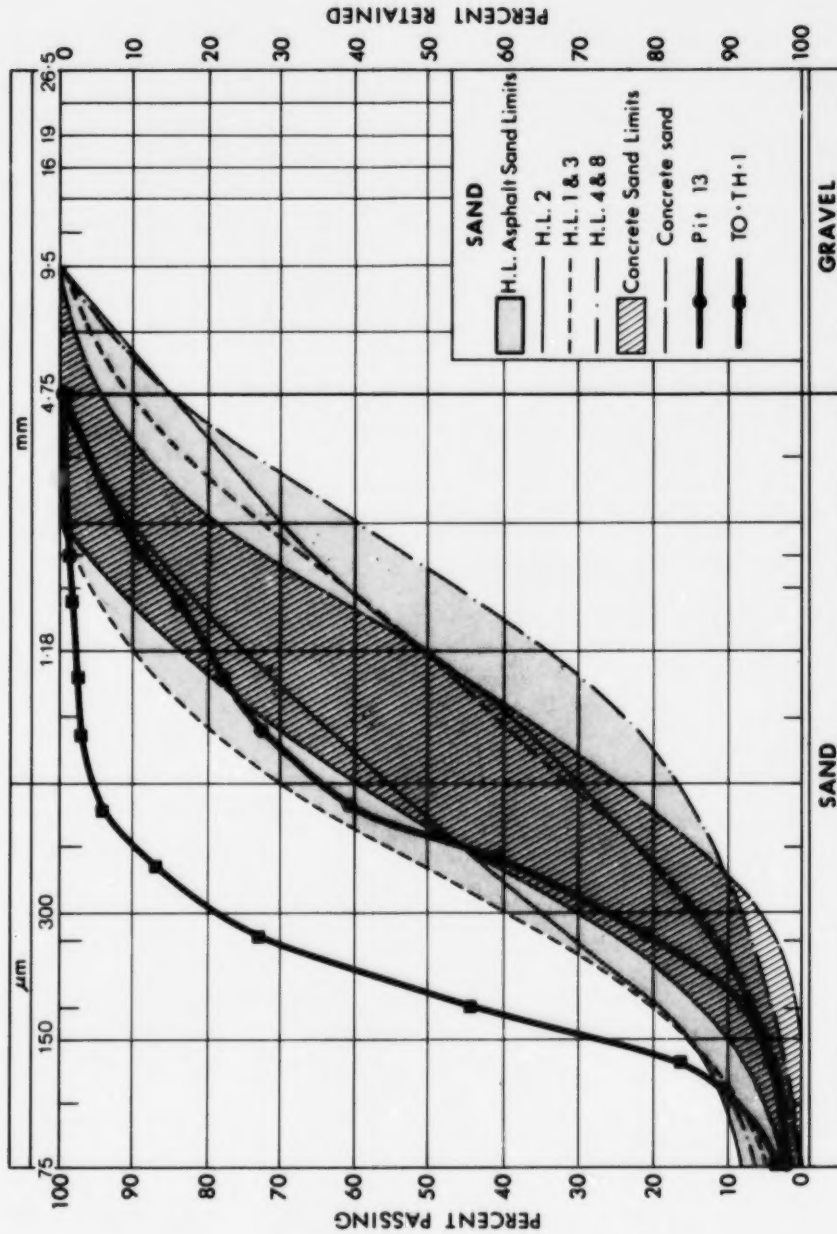


FIGURE 3b: AGGREGATE GRADING CURVES, ESSA TOWNSHIP;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

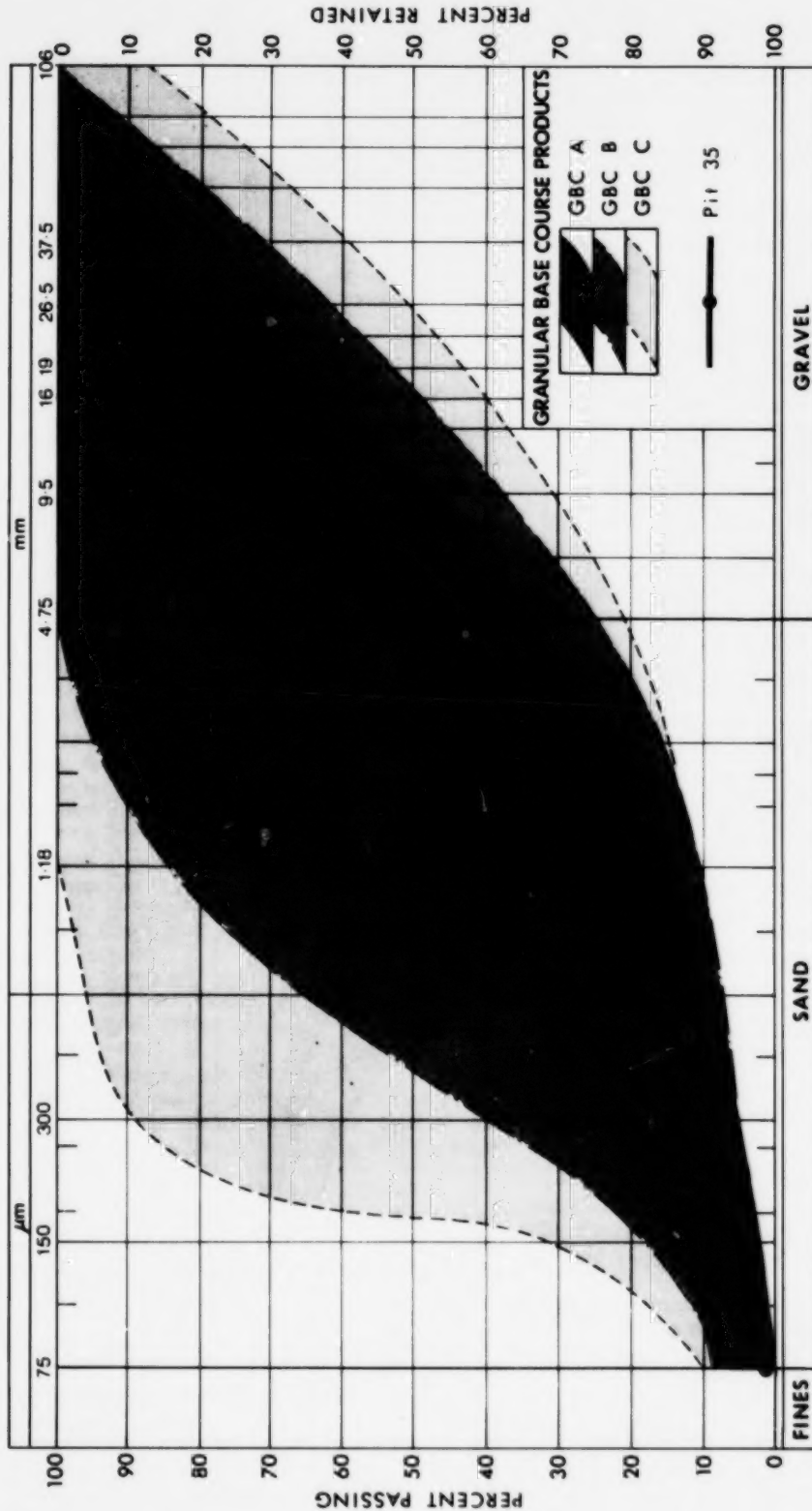


FIGURE 4a: AGGREGATE GRADING CURVES, ESSA TOWNSHIP;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

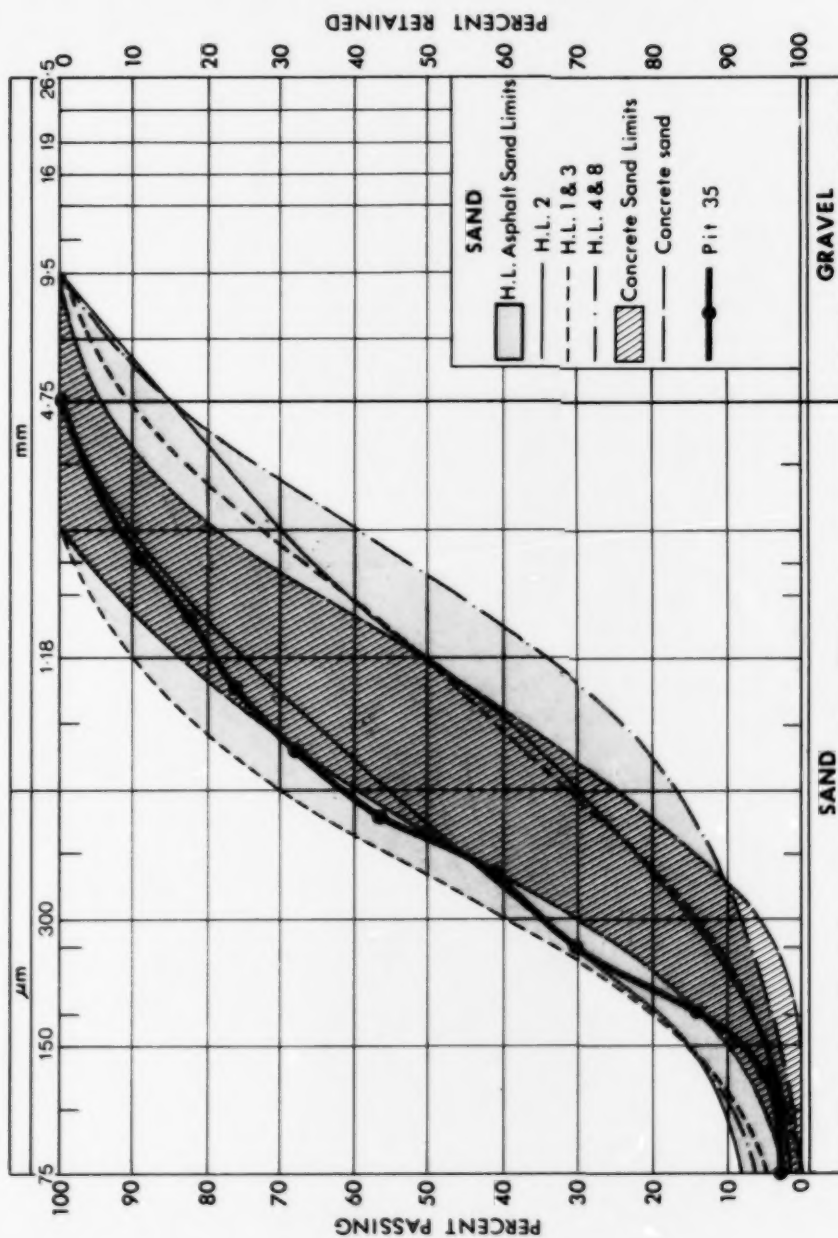


FIGURE 4b: AGGREGATE GRADING CURVES, ESSA TOWNSHIP;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

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Appendix A — Suggested Additional Reading

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Appendix B — Glossary

Abrasion resistance: Tests such as the Los Angeles abrasion test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

Absorption capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Aggregate: Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

Aggregate Abrasion Value: This test directly measures the resistance of aggregate to abrasion with silica sand and a steel disk. The higher the value, the lower the resistance to abrasion. For high quality asphalt surface course uses, values of less than 6 are desirable.

Alkali-aggregate reaction: A chemical reaction between the alkalis of portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

Beneficiation: Beneficiation of aggregates is a process or combination of processes which improves the quality (physical properties) of a mineral aggregate and is not part of the normal processing for a particular use, such as routine crushing, screening, washing or classification. Heavy media separation, jigging, or application of special crushers (e.g. "cage mill") are usually considered processes of beneficiation.

Blending: Required in cases of extreme coarseness, fineness, or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

Bulk Relative Density: An aggregate with low relative density is lighter in weight than one with a high relative density. Low relative density aggregates (less than about 2.5) are often non-durable for many aggregate uses.

Cambrian: The first period of the Paleozoic Era, thought to have covered the time between 570 and 500 million years ago. The Cambrian precedes the Ordovician Period.

Clast: An individual constituent, grain or fragment of a sediment or rock, produced by the mechanical weathering of larger rock mass. Synonyms include particle and fragment.

Crushable aggregate: Unprocessed gravel containing a minimum of 35 percent coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20 percent greater than the 26.5 mm sieve.

Deleterious lithology: A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

Devonian: A period of the Paleozoic Era thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

Dolostone: A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

Drift: A general term for all unconsolidated rock debris transported from one place and deposited in another, distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

Drumlin: A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were formed beneath an advancing ice sheet, and were shaped by its flow.

Eolian: Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

Fines: A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

Glacial lobe: A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced then melted back numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

Gradation: The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm
Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Silt, Clay	less than 0.075 mm

Granular base course: Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

Hot-laid (or asphaltic) aggregate: Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3 and 4), or as binder course (H.L. 2 and 8) used to bind the surface course to the underlying granular base course.

Lithology: The description of rocks on the basis of such characteristics as color, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock.

Los Angeles Abrasion and Impact Test: This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported, and placed. Values less than about 35 percent indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45 percent indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

Magnesium sulphate soundness test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible to freezing and thawing will usually break down and give high losses in this test. Values greater than about 12 to 15 percent indicate potential problems for concrete and asphalt coarse aggregate.

Meltwater channel: A drainage way, often terraced, produced by water flowing away from a melting glacier margin.

Ordovician: an early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

Paleozoic era: One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into six geologic periods, of which only four (Cambrian, Ordovician, Silurian and Devonian) can be recognized in southern Ontario.

Petrographic examination: Individual aggregate particles in a sample are divided into categories good, fair, poor, and deleterious, based on their rock type (petrography) and knowledge of past field performance. A petrographic number (PN) is calculated. The higher the PN, the lower the quality of the aggregate.

Pleistocene: An epoch of the recent geological past including the time from approximately 2 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

Polished Stone Value: This test measures the frictional properties of aggregates after 6 hours of abrasion and polishing with an emery abrasive. The higher the PSV, the higher the frictional properties of the aggregate. Values less than 45 indicate marginal frictional properties, while values greater than 55 indicate excellent frictional properties.

Possible resource: Reserve estimates based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

Precambrian: The earliest geological period extending from the consolidation of the earth's crust to the beginning of the Cambrian.

Shale: A fine-grained, sedimentary rock formed by the consolidation of clay, silt or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone and mudstone.

Silurian: An early period of the Paleozoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

Soundness: The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

Till: Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

AGGREGATE RESOURCES INVENTORY:

Wisconsinan: Pertaining to the last glacial period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial

deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

Appendix C — Geology of Sand and Gravel Deposits

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

Ice-Contact Terraces (ICT): These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous because of extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive because of the variability of the deposits both in terms of quality and grain size distribution.

Kames (K): Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits, producing internal structures characterized by bedding discontinuities. The deposits consist mainly of irregularly bedded and crossbedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt and clay-sized particles).

Eskers (E): Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the sur-

rounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

Undifferentiated Ice-Contact Stratified Drift (IC): This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits because of their lack of continuity and grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

Outwash (OW): Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

Alluvium (AL): Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and they have generally low value because of the presence of excess silt- and clay-sized material. There are few large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

Glaciolacustrine Beach Deposits (LB): These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the source material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

Glaciolacustrine Deltas (LD): These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

Glaciolacustrine Plains (LP): The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources because of their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

End Moraines (EM): These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice-contact stratified drift and in such instances are usually called kame

moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

Windblown Deposits (WD): Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always consists of fine to coarse sand and are usually well sorted. The probability of locating crushable aggregate in windblown deposits is very low.

Appendix D — Geology of Bedrock Deposits

The purpose of this appendix is to familiarize the reader with the general bedrock geology of southern Ontario (Figure 5), and the potential uses of the various bedrock formations where known. The reader is cautioned against using this information for more specific purposes. The stratigraphic chart (Figure 6) is intended only to illustrate the stratigraphic sequences in particular geographic areas and should not be used as a regional correlation table.

The following description is arranged in ascending stratigraphic order, on a group and formation basis. Precambrian rocks are not discussed. Additional stratigraphic information is included for some formations where necessary. The publications and maps of the Ontario Geological Survey and the Geological Survey of Canada should be referred to for more detailed information. The composition, thick-

ness, and uses of the formations are discussed. If a formation may be suitable for use as aggregate and aggregate suitability test data is available, the data has been included in the form of ranges. The following short forms have been used in presenting this data: PSV = Polished Stone Value, AAV = Aggregate Abrasion Value, $MgSO_4$ = Magnesium Sulphate Soundness Test (loss in percent), LA = Los Angeles Abrasion and Impact Test (loss in percent), Absn = Absorption (percent), BRD = Bulk Relative Density, PN (Asphalt & Concrete) = Petrographic Number for Asphalt and Concrete use.

The ranges are intended as a guide only and care should be exercised in extrapolating the information to specific situations. Aggregate suitability test data has been provided by the Ontario Ministry of Transportation.

Covey Hill Formation (Cambrian)

STRATIGRAPHY: lower formation of the Potsdam Group. COMPOSITION: interbedded non-calcareous feldspathic conglomerate and sandstone. THICKNESS: 0 to 45 feet (0 to 14 m). USES: has been quarried for aggregate in South Burgess Township, Leeds County.

Nepean Formation (Cambro-Ordovician)

STRATIGRAPHY: upper formation of the Potsdam Group. COMPOSITION: thin-bedded to massive quartz sandstone with some conglomerate interbeds and rare shaly partings. THICKNESS: 0 to 100 feet (0 to 30 m). USES: suitable as dimension stone; quarried at Philippsville and Forfar for silica sand; alkali-silica reactive in Portland cement concrete. AGGREGATE SUITABILITY TESTING: PSV = 54-68, AAV = 4-15, $MgSO_4$ = 9-32, LA = 44-90, Absn = 1.6-2.6, BRD = 2.38-2.50, PN (Asphalt & Concrete) = 130-140.

March Formation (Lower Ordovician)

STRATIGRAPHY: lower formation of the Beekmantown Group. COMPOSITION: interbedded quartz sandstone, dolomitic quartz sandstone, sandy dolostone and dolostone. THICKNESS: 60 to 197 feet (18 to 60 m). USES: quarried extensively for aggregate in area of subcrop and outcrop; alkali-silica reactive in Portland cement concrete; lower part of formation is an excellent source of skid-resistant aggregate. Suitable for use as facing stone and paving stone. AGGREGATE SUITABILITY TESTING: PSV = 55-60, AAV = 4-6, $MgSO_4$ = 1-17, LA = 15-38, Absn = 0.5-0.9, BRD = 2.61-2.65, PN (Asphalt & Concrete) = 110-150.

Oxford Formation (Lower Ordovician)

STRATIGRAPHY: upper formation of the Beekmantown Group. COMPOSITION: thin- to thick-bedded, micro-crystalline to medium-crystalline, grey dolostone with thin shaley interbeds. THICKNESS: 200 to 335 feet (61 to 102 m). USES: quarried in the Brockville and Smith Falls areas and south of Ottawa for use as aggregate. AGGREGATE SUITABILITY TESTING: PSV = 47-48, AAV = 7-8, $MgSO_4$ = 1-4, LA = 18-23, Absn = 0.7-0.9, BRD = 2.74-2.78, PN (Asphalt & Concrete) = 105-120.

Rockcliffe Formation (Middle Ordovician)

STRATIGRAPHY: divided into lower member and upper (St. Martin) member. COMPOSITION: interbedded quartz sandstone and shale; interbedded shaly bioclastic limestone and shale predominating in upper member to the east. THICKNESS: 0 to 410 feet (0 to 125 m). USES: upper member has been quarried east of Ottawa for aggregate; lower member has been used as crushed stone; some high purity limestone beds in upper member may be suitable for use as fluxing stone and in lime production. AGGREGATE SUITABILITY TESTING: PSV = 58-63, AAV = 10-11, $MgSO_4$ = 12-40, LA = 25-28, Absn = 1.8-1.9, BRD = 2.55-2.62, PN (Asphalt & Concrete) = 122-440.

Shadow Lake Formation (Middle Ordovician)

STRATIGRAPHY: eastern Ontario - the basal unit of the Ottawa Group; central Ontario - overlain by the Simcoe Group. COMPOSITION: in eastern Ontario - silty and sandy dolostone with shale partings and minor interbeds of sandstone; in central Ontario - conglomerates, sandstones, and shales. THICKNESS: eastern Ontario - 7 to 10 feet (2 to 3 m); central Ontario - 0 to 40 feet (0 to 12 m). USES: potential source of decorative stone; very limited value as aggregate source.

Gull River Formation (Middle Ordovician)

STRATIGRAPHY: Part of the Simcoe Group (central Ontario) and Ottawa Group (eastern Ontario). In central and eastern Ontario the formation is subdivided into upper and lower members; west of Lake Simcoe it is presently subdivided into upper, middle and lower members. COMPOSITION: in central and eastern Ontario the lower member consists of alternating units of limestone, dolomitic limestone, and dolostone, the upper member consists of thin-bedded limestones with thin shale partings; west of Lake Simcoe the lower member is thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone whereas the upper and middle members are dense microcrystalline limestones with argillaceous dolostone interbeds. THICKNESS: 23 to 204 feet (7 to 62 m). USES: Quarried in the Lake Simcoe,

Kingston, Ottawa, and Cornwall areas for crushed stone. Rock from certain layers in eastern and central Ontario has proven to be alkali-reactive when used in Portland cement concrete (alkali-carbonate reaction). AGGREGATE SUITABILITY TESTING: PSV = 41-49, AAV = 8-12, $MgSO_4$ = 3-13, LA = 18-28, Absn = 0.3-0.9, BRD = 2.68-2.73, PN (Asphalt & Concrete) = 100-153.

Bobcaygeon Formation (Middle Ordovician)

STRATIGRAPHY: Part of the Simcoe Group (central Ontario) and the Ottawa Group (eastern Ontario), subdivided into upper, middle and lower members; members in eastern and central Ontario are approximately equivalent. COMPOSITION: homogeneous, massive to thin-bedded fine-crystalline limestone with numerous shaly partings in the middle member. THICKNESS: 80 to 285 feet (24 to 87 m). USES: Quarried at Brechin, Marysville, and in the Ottawa area for crushed stone. Generally suitable for use as granular base course aggregate. Rock from certain layers has been found to be alkali-reactive when used in Portland cement concrete (alkali-silica reaction). AGGREGATE SUITABILITY TESTING: PSV = 47-51, AAV = 14-23, $MgSO_4$ = 1-40, LA = 18-32, Absn = 0.3-2.4, BRD = 2.5-2.69, PN (Asphalt & Concrete) = 100-320.

Verulam Formation (Middle Ordovician)

STRATIGRAPHY: part of Simcoe and Ottawa Groups. COMPOSITION: fossiliferous, pure to argillaceous limestone interbedded with calcareous shale. THICKNESS: 105 to 230 feet (32 to 70 m). USES: Quarried at Picton and Bath for use in cement manufacture. Quarried for aggregate in Mara Township, Simcoe County and in the Belleville-Kingston area. May be unsuitable for use as aggregate in some areas because of its high shale content. AGGREGATE SUITABILITY TESTING: PSV = 43-44, AAV = 9-13, $MgSO_4$ = 4-45, LA = 22-29, Absn = 0.4-2.1, BRD = 2.59-2.70, PN (Asphalt & Concrete) = 120-255.

Lindsay Formation (Middle and Upper Ordovician)

STRATIGRAPHY: Part of Simcoe and Ottawa Groups; in eastern Ontario is divisible into an unnamed lower member and the Eastview Member; in central Ontario is divisible into the Collingwood Member (equivalent to portions of the Eastview Member) and a lower member. COMPOSITION: eastern Ontario - the lower member is interbedded, very fine- to coarse-crystalline limestone with undulating shale partings and interbeds of dark grey calcareous shale, whereas the Eastview Member is an interbedded dark grey to dark brown calcareous shale and very fine- to fine-crystalline, petroliferous limestone; central Ontario - Collingwood Member is a black, calcareous shale whereas the lower member is a very fine- to coarse-crystalline, thin-bedded limestone with very thin, undulating shale partings. THICKNESS: 82 to 200 feet (25 to 61 m). USES: eastern Ontario - lower member is used extensively for aggregate production; central Ontario - quarried at Picton, Ogden Point and Bowmanville for cement. May be suitable or unsuitable for use as concrete and asphalt aggregate. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 2-47,

LA = 20-28, Absn = 0.4-1.3, BRD = 2.64-2.70, PN (Asphalt & Concrete) = 110-215.

Blue Mountain and Billings Formations (Upper Ordovician)

STRATIGRAPHY: central Ontario - Blue Mountain Formation includes the upper and middle members of the former Whitby Formation; eastern Ontario - Billings Formation is equivalent to part of the Blue Mountain Formation. COMPOSITION: Blue Mountain Formation - blue-grey, noncalcareous shales; Billings Formation - dark grey to black, noncalcareous to slightly calcareous, pyritiferous shale with dark grey limestone laminae and grey siltstone interbeds. THICKNESS: Blue Mountain Formation - 140 to 200 feet (43 to 61 m); Billings Formation - 0 to 205 feet (0 to 62 m). USES: Billings Formation may be a suitable source for structural clay products and expanded aggregate; Blue Mountain Formation may be suitable for structural clay products.

Georgian Bay and Carlsbad Formations (Upper Ordovician)

COMPOSITION: central Ontario - Georgian Bay Formation composed of interbedded limestone and shale; eastern Ontario - Carlsbad Formation composed of interbedded shale, siltstone and bioclastic limestone; THICKNESS: Georgian Bay Formation - 300 to 560 feet (91 to 170 m); Carlsbad Formation - 0 to 610 feet (0 to 186 m). USES: Georgian Bay Formation - used by several producers in Metropolitan Toronto area to produce brick and structural tile, as well as for making portland cement; at Streetsville, expanded shale was used in the past to produce lightweight aggregate. Carlsbad Formation - used as a source material for brick and tile manufacturing, has potential as a lightweight expanded aggregate.

Queenston Formation (Upper Ordovician)

COMPOSITION: Red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. THICKNESS: 400 to 500 feet (122 to 152 m). USES: There are several large quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa. All extract shale for brick manufacturing. The Queenston Formation is the most important source material for brick manufacture in Ontario.

Whirlpool Formation (Lower Silurian)

STRATIGRAPHY: lower formation in the Cataract Group in the Niagara Peninsula and the Niagara Escarpment as far north as Duntroon. COMPOSITION: massive, medium- to coarse-grained, argillaceous white to light grey quartz sandstone with thin grey shale partings. THICKNESS: 0 to 25 feet (0 - 8 m). USES: building stone, flagstone.

Manitoulin Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs north of Stoney Creek. COMPOSITION: thin-bedded, blue-grey to buff-brown dolomitic limestones and dolostones. THICKNESS: 0 to 75 feet (0 to 23 m). USES: extracted for crushed stone in St. Vincent

Township, Grey County, and for decorative stone on Manitoulin Island. AGGREGATE SUITABILITY TESTING: No data.

Cabot Head Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs throughout southern Ontario, south and north of the Niagara Escarpment. COMPOSITION: green, grey and red shales. THICKNESS: 50 to 60 feet (15 to 18 m); USES: potential source of coated lightweight aggregate and raw material for use in manufacture of brick and tile. Lack of suitability exposures has limited use.

Grimsby Formation

STRATIGRAPHY: upper formation of the Cataract Group, is identified on the Niagara Peninsula as far north as Clappison's Corners. COMPOSITION: interbedded sandstone and shale, mostly red. THICKNESS: 0 to 50 feet (0 to 15 m). USES: no present uses.

Thorold Formation (Middle Silurian)

STRATIGRAPHY: lower formation in the Clinton Group on the Niagara Peninsula. COMPOSITION: thick-bedded quartz sandstone. THICKNESS: 7 to 10 feet (2 - 3 m). USES: no present uses.

Neagha Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on the Niagara Peninsula. COMPOSITION: dark-grey to green shale with minor interbedded limestone. THICKNESS: 0 to 5 feet (0 to 2 m). USES: no present uses.

Dyer Bay Formation (Middle Silurian)

STRATIGRAPHY: lower formation in the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: highly fossiliferous, impure dolostone. THICKNESS: 0 to 20 feet (0 to 6 m). USES: no present uses.

Wingfield Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: olive green to grey shale with dolostone interbeds. THICKNESS: 0 to 36 feet (0 to 11 m). USES: no present uses.

St. Edmund Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula, upper portion previously termed the Mindemoya Formation. COMPOSITION: pale grey to buff-brown, micro- to medium-crystalline, thin- to medium-bedded dolostone. THICKNESS: 0 to 85 feet (0 to 26 m). USES: quarried for fill and crushed stone on Manitoulin Island. AGGREGATE SUITABILITY TESTING: $MgSO_4 = 1-2$, $LA = 19-21$, $Absn = 0.6-0.7$, $BRD = 2.78-2.79$, PN (Asphalt & Concrete) = 105.

Fossil Hill and Reynales Formations (Middle Silurian)

STRATIGRAPHY: part of Clinton Group; Fossil Hill Formation occurs in the northern part of the Niagara Escarpment and is approximately equivalent in part to the Reynales Formation which occurs on the Niagara Peninsula and the Escarpment as far north as the Forks of the Credit. COMPOSITION: Fossil Hill Formation - fine- to coarse-crystalline dolostone with high silica content; Reynales Formation - thin- to thick-bedded shaly dolostone and dolomitic limestone. THICKNESS: Fossil Hill Formation - 20 to 85 feet (6 to 26 m); Reynales Formation - 0 to 10 feet (0 to 3 m). USES: both formations quarried for aggregate with overlying Amabel and Lockport Formations. AGGREGATE SUITABILITY TESTING: (Fossil Hill Formation on Manitoulin Island) $MgSO_4 = 41$, $LA = 29$, $Absn = 4.1$, $BRD = 2.45$, PN (Asphalt & Concrete) = 370.

Irondequoit Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group on the Niagara Peninsula south of Waterdown. COMPOSITION: massive, coarse-crystalline crinoidal limestone. THICKNESS: 0 to 7 feet (0 to 2 m). USES: not significantly utilized.

Rochester Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group along the Niagara Peninsula. COMPOSITION: black to dark grey calcareous shale with numerous limestone lenses. THICKNESS: 15-60 feet (5-18 m). USES: not significantly utilized. AGGREGATE SUITABILITY TESTING: $PSV = 69$, $AAV = 17$, $MgSO_4 = 95$, $LA = 19$, $Absn = 2.2$, $BRD = 2.67$, PN (Asphalt & Concrete) = 400.

Decew Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group south of Waterdown along the Niagara Peninsula. COMPOSITION: sandy to shaly dolomitic limestone and dolostone. THICKNESS: 0 to 15 feet (0 to 5 m). USES: too shaly for high quality uses, but is quarried along with Lockport Formation in places. AGGREGATE SUITABILITY TESTING: $PSV = 67$, $AAV = 15$, $MgSO_4 = 55$, $LA = 21$, $Absn = 2.2$, $BRD = 2.66$, PN (Asphalt & Concrete) = 255.

Lockport and Amabel Formations (Middle Silurian)

STRATIGRAPHY: Lockport Formation occurs from Waterdown to Niagara Falls, subdivided into 3 formal members: Gasport, Goat Island and Eramosa Members and an informal member (the "Vinemount shale beds"); the stratigraphically equivalent Amabel Formation, found from Waterdown to Cockburn Island, is subdivided into Lions Head, Wiarton/Colpoy Bay, and Eramosa Members. COMPOSITION: Lockport Formation is thin- to massive-bedded, fine- to medium-crystalline dolostone; Amabel Formation is thin bedded to massive, medium-crystalline dolostone with reef facies near Georgetown and on the Bruce Peninsula. THICKNESS: (Lockport/ Amabel) 10 to 130 feet (3 to 40 m). USES: both formations have been used to produce lime, crushed stone, concrete aggregate, and building stone throughout their area of occurrence, and are a resource of provincial significance.

AGGREGATE SUITABILITY TESTING: PSV = 36-49, AAV = 10-17, $MgSO_4$ = 2-6, LA = 25-32, Absn = 0.4-1.54, BRD = 2.61-2.81, PN (Asphalt & Concrete) = 100-105.

Guelph Formation (Middle Silurian)

STRATIGRAPHY: Exposed on the Niagara Escarpment from the Niagara River to the tip of the Bruce Peninsula, mostly present in the subsurface of southwestern Ontario. COMPOSITION: Micro-crystalline to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies of high chemical purity. THICKNESS: 100 to 170 feet (30 to 52 m). USES: Some areas appear soft and unsuitable for use in the production of load-bearing aggregate. This unit requires additional testing to fully establish its aggregate suitability. Main use is for dolomitic lime for cement manufacture. Quarried near Hamilton and Guelph.

Salina Formation (Upper Silurian)

STRATIGRAPHY: present in the subsurface of southwestern Ontario; only rarely exposed at the surface. COMPOSITION: grey and maroon shale, brown dolostone and, in places, salt, anhydrite and gypsum; consists predominantly of evaporitic rich material with up to eight units identifiable. THICKNESS: 370 to 600 feet (113 to 183 m). USES: Gypsum mines at Hagersville, Caledonia, and Drumbo. Salt is mined at Goderich and Windsor and is produced from brine wells at Amherstburg, Windsor and Sarnia.

Bertie and Bass Islands Formations (Upper Silurian)

STRATIGRAPHY: Bertie Formation found in southern Niagara Peninsula; Bass Islands Formation, the Michigan Basin equivalent of the Bertie Formation, does not significantly outcrop in Ontario but is present in the subsurface in southwestern Ontario; Bertie Formation represented by Oatka, Falkirk, Scajaquanda, Williamsville, and Akron Members. COMPOSITION: medium- to massive-bedded, micro-crystalline, brown dolostone with shaly partings. THICKNESS: 45 to 160 feet (14 to 49 m). USES: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville and Dunnville; shaly intervals are unsuitable for use as high specification aggregate because of low freeze-thaw durability. Has also been extracted for lime. AGGREGATE SUITABILITY TESTING: PSV = 46-49, AAV = 8-11, $MgSO_4$ = 4-19, LA = 14-23, Absn = 0.8-2.5, BRD = 2.61-2.78, PN (Asphalt & Concrete) = 102-120.

Oriskany Formation (Lower Devonian)

STRATIGRAPHY: basal Devonian clastic unit, found in Niagara Peninsula. COMPOSITION: thick- to massive-bedded, coarse-grained, grey-yellow sandstone. THICKNESS: 0 to 15 feet (0 to 5 m). USES: Has been quarried for silica sand, building stone, and armour stone. May be acceptable for use as rip rap, and well cemented varieties may be acceptable for some asphaltic products. AGGREGATE SUITABILITY TESTING: (of a well cemented variety of the formation) PSV =

64, AAV = 6, $MgSO_4$ = 2, LA = 29, Absn = 1.2-1.3, BRD = 2.55, PN (Asphalt & Concrete) = 107.

Bois Blanc Formation (Lower Devonian)

STRATIGRAPHY: Springvale Sandstone Member forms the lower portion of formation. COMPOSITION: a cherty limestone with shale partings and minor interbedded dolostones; Springvale Sandstone Member is a medium- to coarse-grained, green glauconitic sandstone with interbeds of limestone, dolostone and brown chert. THICKNESS: 10 to 130 feet (3 to 40 m). USES: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. Material generally unsuitable for concrete aggregate because of high chert content. AGGREGATE SUITABILITY TESTING: PSV = 48-53, AAV = 3-7, $MgSO_4$ = 3-18, LA = 15-22, Absn = 1.3-2.8, BRD = 2.50-2.70, PN (Asphalt & Concrete) = 102-290.

Onondaga Formation (Middle Devonian)

STRATIGRAPHY: correlated to part of the Detroit River Group; occurs on the Niagara Peninsula from Simcoe to Niagara Falls; contains the Edgecliff, Clarence, and Moorehouse Members. COMPOSITION: medium-bedded, fine- to coarse-grained, dark grey-brown or purplish-brown, variably cherty limestone. THICKNESS: 60 to 82 feet (18 to 25 m). USES: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High chert content makes much of the material unsuitable for use as concrete aggregate and asphaltic concrete. Has been used as a raw material in cement manufacture. AGGREGATE SUITABILITY TESTING: (Clarence and Edgecliff Members) $MgSO_4$ = 1-6, LA = 16.8-22.4, Absn = 0.5-1.1, PN (Asphalt & Concrete) = 190-276.

Amherstburg Formation (Middle Devonian)

STRATIGRAPHY: part of Detroit River Group; correlated to Onondaga Formation in Niagara Peninsula; contains Sylvania Sandstone Member and Formosa Reef Limestone. COMPOSITION: bituminous, bioclastic, stromatoporoid-rich limestone with grey chert nodules; Formosa Reef Limestone - high purity (calcium rich) limestone; Sylvania Sandstone Member - quartz sandstone. THICKNESS: 0 to 165 feet (0 to 50 m); Formosa Reef Limestone - up to 85 feet (26 m). USES: cement manufacture, agricultural lime, aggregate. AGGREGATE SUITABILITY TESTING: PSV = 57, AAV = 19, $MgSO_4$ = 9-35, LA = 26-52, Absn = 1.1-6.4, BRD = 2.35-2.62, PN (Asphalt & Concrete) = 105-300.

Lucas Formation (Middle Devonian)

STRATIGRAPHY: part of the Detroit River Group in southwestern Ontario; includes the Anderdon Member which, in the Woodstock Beachville area, may constitute the bulk of the formation. COMPOSITION: light brown or grey-brown dolostone with bituminous laminations and minor chert; Anderdon Member consists of very high purity (calcium-rich) limestone. THICKNESS: 130 to 246 feet (40 to 75 m). USES: Most important source of high-purity limestone in Ontario. Used as calcium lime for metallurgical flux and for the manufacture of chemicals. Rock of lower purity is

used for cement manufacture, agricultural lime and aggregate. Anderdon Member is quarried at Amherstburg for crushed stone. AGGREGATE SUITABILITY TESTING: PSV = 46-47, AAV = 15-16, $MgSO_4$ = 2-60, LA = 22-47, Absn = 1.1-6.5, BRD = 2.35-2.40, PN (Asphalt & Concrete) = 110-160.

Dundee Formation (Middle Devonian)

STRATIGRAPHY: few natural outcrops, largely in the subsurface of southwestern Ontario. COMPOSITION: Fine- to medium-crystalline, brownish-grey, medium- to thick-bedded, dolomitic limestone with shaly partings sandy layers, and chert in some areas. THICKNESS: 50 to 100 feet (15 to 30 m). USES: Quarried near Port Dover and on Pelee Island for crushed stone. Used at St. Marys as a raw material for portland cement. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 1-28, LA = 22-46, Absn = 0.6-6.8, PN (Asphalt & Concrete) = 125-320.

Marcellus Formation (Middle Devonian)

STRATIGRAPHY: subsurface unit, mostly found below Lake Erie and extending into the eastern U.S.A., pinches out in the Port Stanley area. COMPOSITION: black, bituminous shales. THICKNESS: 0 to 15 feet (0 to 5 m). USES: no present uses.

Bell Formation (Middle Devonian)

STRATIGRAPHY: lowest formation of the Hamilton Group, no out-crop in Ontario. COMPOSITION: soft blue and grey calcareous shale. THICKNESS: 0 to 30 feet (0 to 9 m). USES: no present uses.

Rockport Quarry Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group; no out-crop in Ontario. COMPOSITION: grey-brown, very fine-grained limestone with occasional shale layers. THICKNESS: 0 to 20 feet (0 to 6 m). USES: no present uses.

Arkona Formation (Middle Devonian)

STRATIGRAPHY: Part of the Hamilton Group. COMPOSITION: blue-grey, plastic, clay shale with occasional thin and laterally discontinuous limestone lenses. THICKNESS: 15 to 120 feet (5 to 37 m). USES: has been extracted at Thedford and near Arkona for the production of drainage tile.

Hungry Hollow Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: grey crinoidal limestone and soft, fos-

siliferous calcareous shale. THICKNESS: 0 to 6 feet (0 to 2 m). USES: suitable for some crushed stone and fill with selective quarrying. AGGREGATE SUITABILITY TESTING: No data.

Widder Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: mainly soft, grey, fossiliferous calcareous shale interbedded with blue-grey, fine-grained fossiliferous limestone. THICKNESS: 0 to 45 feet (0 to 14 m). USES: no present uses.

Ipperwash Formation (Middle Devonian)

STRATIGRAPHY: upper formation of the Hamilton Group; very limited distribution. COMPOSITION: medium- to coarse grained, grey-brown, bioclastic limestone. THICKNESS: 5 to 45 feet (2-14 m). USES: no present uses.

Kettle Point Formation (Upper Devonian)

STRATIGRAPHY: occurs in a band between Sarnia and Erieau; small part overlain by Port Lambton Group rocks in extreme northwest. COMPOSITION: black, highly fissile, organic-rich shale with minor interbeds of grey-green silty shale. THICKNESS: 0 to 200 feet (0 to 61 m). USES: possible source of fill; possible source of material for use as sintered lightweight aggregate.

Bedford Formation (Upper Devonian)

STRATIGRAPHY: lower formation of the Port Lambton Group. COMPOSITION: soft, grey shale. THICKNESS: 0 to 108 feet (0 to 33 m). USES: no present uses.

Berea Formation (Upper Devonian)

STRATIGRAPHY: middle formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: grey, fine to medium grained sandstone, often dolomitic and interbedded with grey shale and siltstone. THICKNESS: 0 to 197 feet (0 to 60 m). USES: no present uses.

Sunbury Formation (Upper Devonian)

STRATIGRAPHY: upper formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: black shale. THICKNESS: 0 to 66 feet (0 to 20 m). USES: no present uses.

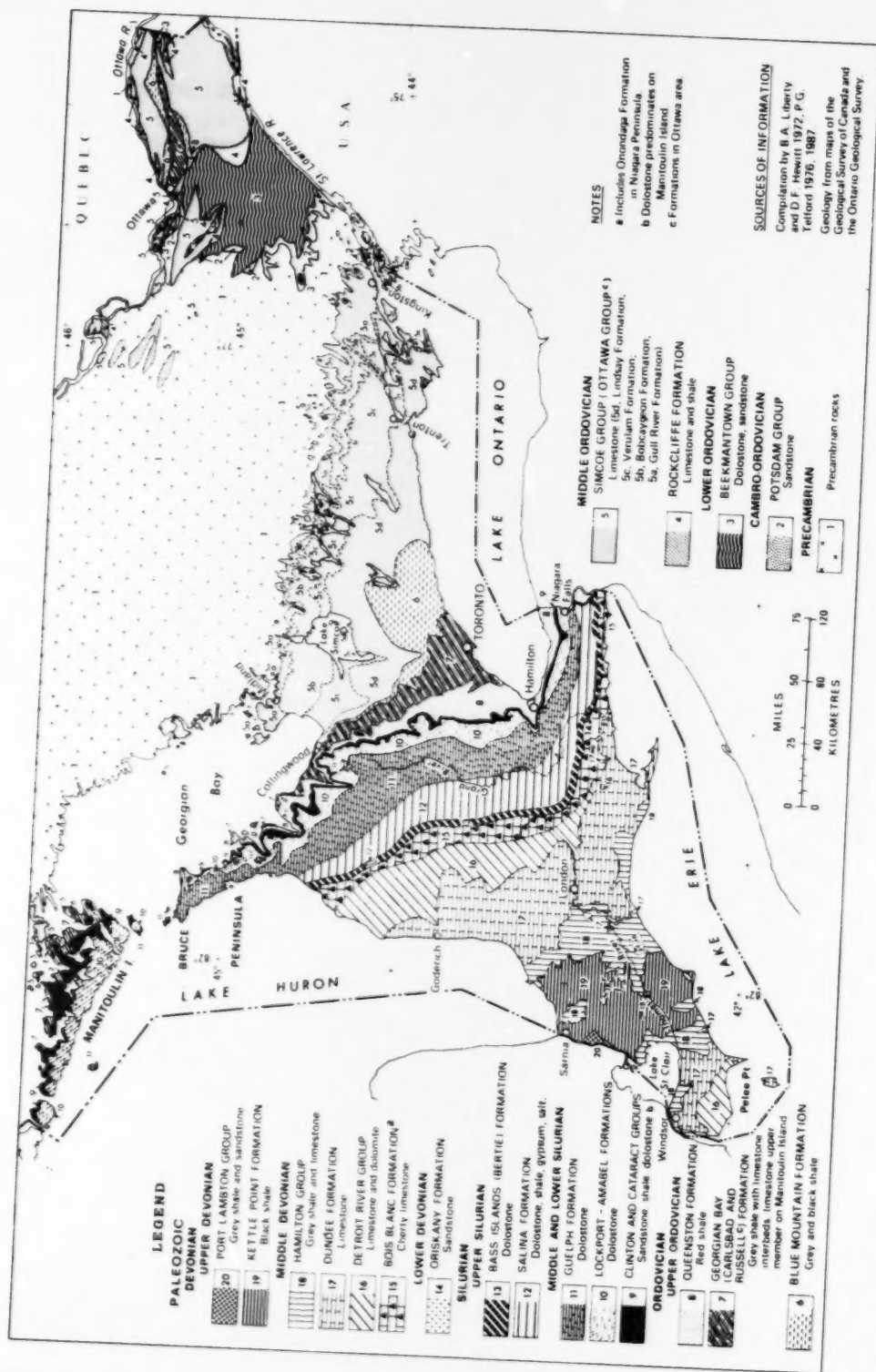


Figure 5. Bedrock Geology of Southern Ontario.

		SOUTHWESTERN ONTARIO		NIAGARA PENINSULA SIMCOE - NIAGARA FALLS	NIAGARA ESCARPMENT NORTH OF HAMILTON TO MANITOULIN ISLAND	CENTRAL ONTARIO	EASTERN ONTARIO
DEVONIAN	U	Port Lambton Gp.					
		Kettle Point Fm.					
	M	Hamilton Gp.					
		Marcellus Fm.					
		Dundee Fm.	Dundee Fm.				
			Lucas Fm.				
		Detroit River Gp.	Onondaga Fm.				
	L	Bois Blanc Fm.	Bois Blanc Fm.				
SILURIAN		Bass Islands Fm.	Bertie Fm.				
	U	Salina Fm.	Salina Fm.				
	M		Guelph Fm.	Guelph Fm. *			
	L		Lockport Fm.	Lockport/Amabel Fm.			
ORDOVICIAN			Clinton Gp.	Clinton Gp.			
			Cataract Gp.	Cataract Gp.			
	U		Queenston Fm.	Queenston Fm. *	Queenston Fm.	Queenston Fm.	Queenston Fm.
				Georgian Bay Fm.	Georgian Bay Fm.	Georgian Bay Fm.	Georgian Bay Fm.
				Blue Mountain Fm.	Blue Mountain Fm.	Billings Fm.	
				Collingwood Mbr.	Collingwood Mbr.	Eastview Mbr.	
	M				Lindsay Fm.	Lindsay Fm.	
					Verulam Fm.	Verulam Fm.	
					Bobcaygeon Fm.	Bobcaygeon Fm.	
					Gull River Fm.	Gull River Fm.	
					Shadow Lake Fm.	Shadow Lake Fm.	
	L					Rockcliffe Fm.	
CAMBRIAN						Oxford Fm.	
						March Fm.	
						Nepean Fm.	
						Covey Hill Fm.	



Units not present because of erosion or non-deposition



Units in subsurface only

Gp. = Group, Fm. = Formation, Mbr. = Member

* Does not occur on Manitoulin Island

Figure 6. Exposed Paleozoic Stratigraphic Sequences in Southern Ontario
(adapted from: Bezys, R.K., and Johnson, M.D.

In Press: The Geology of Paleozoic Formations Utilized by the Limestone Industry of Ontario;
The Canadian Mining and Metallurgical Bulletin).

Appendix E — Aggregate Quality Test Specifications

Four types of aggregate quality tests are often performed by the Ontario Ministry of Transportation on sampled material. A description of each test is found in Appendix B and the specification limits for each test are given in this appendix. Although a specific sample meets or does not meet the specification limits for a certain product, it may or may not be acceptable for that use based on field performance. Additional quality tests other than the four major tests listed in this appendix can be used to determine the suitability of an aggregate. The tests are performed by the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation.

TABLE 10. SELECTED QUALITY REQUIREMENTS FOR MAJOR AGGREGATE PRODUCTS.

TYPE OF MATERIAL	TYPE OF TEST				
	COARSE AGGREGATE				FINE AGGREGATE
	Petrographic Number Maximum	Magnesium Sulphate Soundness - Max. % Loss	Absorption Maximum %	Los Angeles Abrasion Maximum % Loss	Magnesium Sulphate Soundness Maximum % Loss
Granular Base A	200	-	-	60	-
16 mm Crushed Type 'A'	160	-	-	35	-
16 mm Crushed Type 'B'	200	-	-	60	-
Granular Subbase B	250	-	-	-	-
Granular Subbase C	250	-	-	-	-
Granular Subbase D	-	-	-	-	-
Hot Mix - H. L. 1	100	5	1.0	15	16
Hot Mix - H. L. 2	-	-	-	-	20
Hot Mix - H. L. 3	135	12	1.75	35	16
Hot Mix - H. L. 4	160	12	2.0	35	20
Hot Mix - H. L. 8	160	15	2.0	35	20
Structural Concrete and Concrete Base	140	12	2.0	35	16
Pavement Concrete and Exposed Structure Deck	125	12	2.0	35	16

(Ministry of Transportation Forms 1002, 1003 and 1010)

**MAPS
NOT
FILMED**

**CARTES
OMISES**